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ERRATA.

Page 19, line 7 from bottom, *after* the word "open" *insert* "and three rooms high, on the side struck."

Page 154, line 19, *for* 12 *read* 1.

,, ,, ,, 8 from bottom, *for* 116 *read* 216.

,, ,, ,, 8 ,, ,, ,, mean *read* maximum.

,, ,, ,, 2 ,, ,, ,, 990 *read* 900.

Vol. XIII. p. 807, line 16, *for* Dines *read* Owen.

,, XVI, p. 225, ,, 22 from bottom, *for* 1·2 *read* 1·9.

QUARTERLY JOURNAL

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THE RELATION OF GROUND WATER TO DISEASE.

An Address delivered to the Royal Meteorological Society, November 19th, 1890.

BY BALDWIN LATHAM, M.Inst.C.E., F.G.S., F.S.S., F.S.I., &c., PRESIDENT.

(Plates I.-IV.)

THE work in which the Fellows of the Royal Meteorological Society are engaged is one of surpassing importance, as regards the study of the causation of disease. The words written by John R. Arbuthnot, M.D., F.R.S., more than a century and a half ago, are probably as applicable now as when written. He said "a history of facts or a journal of diseases compared with the weather, which, if it should be kept for any great period of time and in many places I will venture to affirm that mankind would arrive at more than a conjectural knowledge in this matter. The ancient physicians seem to have been more attentive to this than the moderns, and those of the moderns who have attended to it have perhaps made no inconsiderable figure in their profession."

Various climatic conditions affect disease; and to get at the particular influence of any one condition it is necessary to differentiate between various causes. The variations in climatic condition are extremely diversified, and the study of their influence on disease should not extend over too great an area; for it is only in typical years that their influence is wide-spread.

In studying the effects of underground water on disease, we must care-

fully eliminate those other agencies which are known to have an influence upon health. The pages of history show that when the ground waters of our own or other countries have arrived at a considerable degree of lowness, as evidenced by the failure of springs and the drying up of rivers, such periods have always been accompanied or followed by epidemic disease.

I may say, at the outset, that in the study of this subject it will be found, in all probability, that ground water in itself, except under conditions where it is liable to pollution, has no material effect in producing or spreading disease. As a rule it is only in those places in which there has been a considerable amount of impurity stored up in the soil that diseases become manifest, and the most common mode by which diseases are disseminated is by means of the water supplies drawn from the ground, or by the introduction of contaminated ground air into the habitations of the people. It will also be found that the periods of low and high ground-water mark those epochs when certain organic changes take place in the impurities stored in the earth, and which ultimately become the cause, and lead to the spread, of disease.

For the purpose of illustrating the influences of ground water upon health I propose to deal more especially with the records of Croydon; not because Croydon is an exceptionally unhealthy district, for it is a district extremely favourable to health by reason of the comparatively recent extension of its population over a maiden soil which has not had time to be polluted by the residence of man upon it. In fact, if you wish to get the true significance of the bearing of climatic influences on health, you must go into those districts which have been long occupied by man as residences, in which the ground has received from year to year considerable accessions of pollution. On this account the observations made at Croydon are unfavourable, but what occurs there is accentuated in other districts not so favourably located. We have, moreover, in Croydon a comparatively perfect register of Baptisms and Burials, going back to the year 1539.

For years past I have been carrying on observations upon the state of the ground water within and around this particular area, with a view of discovering the influences which affect the health of the place, and by inference of all other places. I have had extracted the date, the place, and the cause of every death since registration has taken place, and have also had abstracted the whole of the burials, separating them to each month of every year. The Croydon Register of Burials shows that the incidence of disease in Croydon three hundred years ago did not differ greatly from what is observed at the present time.

Croydon is also by no means a favourable place for the study of certain types of disease, owing to the fact that it has been subject at certain periods to various epidemics, the protective influences of which against a second attack of such disease tends to obscure the law that governs their extension.

One of the climatic conditions which affect health is that of temperature. Heat and cold have a marked influence in producing disease. The month of June is the most healthy month of the whole year. As we leave the point of mean temperature, either on one side or the other, the death rate increases, but from a different class of disease.

The following table shows the death rates in Croydon. In it I have shown the mean temperature of the months of December, January and February

COLD AND HOT PERIODS WITH DEATHS[1] IN CROYDON.

Year.	Temp. Dec. Jan. Feb.	Death Rate, Jan. Feb. March.	Deaths of Children under 5 years of age, Jan. Feb. March.	Temp. June, July, Aug.	Death Rate, July, Aug. Sept.	Deaths of Children under 5 years of age, July, Aug. Sept.
	°			°		
1837	40·5	39·8	..	60·9	28·5	47
1838	39·1	33·7	51	60·2	31·5	55
1839	39·8	22·3	28	60·3	23·3	35
1840	40·4	23·4	31	59·2	23·9	34
1841	34·6	29·1	41	58·2	18·4	28
1842	38·1	31·0	56	62·8	24·1	35
1843	40·3	25·0	29	59·8	21·1	36
1844	39·4	21·8	33	60·0	16·4	22
1845	34·7	23·5	26	59·2	20·0	26
1846	43·1	20·0	32	64·3	18·8	34
1847	34·7	28·3	47	61·8	28·7	56
1848	40·2	33·5	88	59·9	25·6	32
1849	43·0	31·6	47	61·1	31·8	34
1850	39·0	18·2	33	61·7	19·4	30
1851	41·1	19·3	42	60·9	26·0	40
1852	41·3	20·6	44	61·7	22·2	41
1853	40·6	36·8	73	60·1	22·1	33
1854	37·7	24·3	61	59·4	27·6	62
1855	35·3	26·3	48	61·1	18·4	44
1856	39·2	19·1	51	61·5	17·5	36
1857	38·7	18·8	46	64·0	16·1	49
1858	39·5	18·6	35	63·1	18·6	57
1859	41·7	18·4	34	65·0	25·1	91
1860	36·7	18·7	57	57·4	14·8	33
1861	39·1	19·4	46	62·0	16·0	55
1862	40·9	20·9	66	58·6	14·2	40
1863	42·7	20·7	67	61·3	22·2	78
1864	38·8	29·9	112	60·4	18·5	70
1865	·37·4	22·1	82	62·3	21·6	97
1866	42·6	27·5	125	61·1	17·8	78
1867	40·8	22·1	90	60·5	16·8	73
1868	39·6	22·1	105	65·1	25·0	141
1869	44·1	21·7	99	60·2	23·4	135
1870	34·1	20·8	105	62·5	20·2	130
1871	35·8	22·6	133	60·4	22·4	127
1872	41·5	19·5	119	61·7	19·5	126
1873	39·8	17·7	93	61·7	15·7	111
1874	40·3	17·8	101	60·9	15·4	110
1875	37·2	22·1	112	60·3	18·8	125
1876	38·9	21·4	121	62·7	19·9	143
1877	43·7	20·0	130	62·0	15·0	93
1878	41·3	18·0	117	62·0	18·9	164
1879	34·6	21·6	127	58·5	12·9	88
1880	36·0	24·3	130	60·6	24·2	153
1881	37·7	17·7	110	61·2	16·6	149
1882	40·8	21·2	190	59·0	16·3	134
1883	41·5	16·2	117	60·3	12·1	94
1884	42·2	17·7	145	62·1	17·3	171
1885	40·6	19·8	154	60·6	16·3	121
1886	36·3	17·7	126	61·0	15·3	153
1887	36·6	16·0	118	62·8	15·2	143
1888	36·7	16·6	113	58·6	10·8	83
1889	33·3	16·0	126	61·1	13·7	126
1890	38·8	22·2	192	59·6	14·7	142

[1] From Burials.

compared with the number of deaths in January, February and March, and the mean temperature of the months of June, July and August, and compared with it the deaths in July, August and September.

During the period included in this table the population of Croydon has increased from 14,885 in 1837, to 79,615 in 1881, and the population is now estimated by the local authority at over 100,000, a figure, however, which in my judgment is too high.

Although cold is shown to affect health, yet, in all probability, cold is not an important factor as affecting the health of children under five years of age. This has clearly been demonstrated by the fact that the death rate of children in cold countries, such as Norway, is absolutely less than that of England, while in a warm country like Italy the death rate of children is higher than that of England. This latter fact is doubtless partly due to the influences of high temperature, but in the study of the influence of ground water it is found that the deaths of children increase in a remarkable degree at the period of low ground water, and the death rate fluctuates in a singular manner compared with the variation in the annual amount of ground water, the rate being least with the highest and greatest with the lowest ground water. Consequently, if the ground water is plotted on a diagram with ordinates upwards, and the death rate with ordinates downwards, there will be found to be a remarkable parallelism between the lines.[1] We often have the lowest ground waters in the months of the lowest temperature, and, therefore, it becomes necessary to separate the influence of cold from that of lowness of ground water. This country has had the most unhealthy periods when the ground water has been at its lowest. The following table shows the death rates of England and Wales in the first quarters of the respective years, embracing all the known general low water periods that have occurred since the Registration of Deaths was established.

DEATH RATES, ENGLAND AND WALES, IN LOW WATER PERIODS.

First Quarter of Year.

Year.	Death Rate.	Temp. Green-wich.	Year.	Death Rate.	Temp. Green-wich.
1838	26·2	35·8°	1864	27·7	38·1°
1845	25·5	33·6	1865	27·0	36·8
1847	28·5	36·8	1866	26·2	42·0
1848	27·9	40·6	1875	27·5	39·6
1853	26·1	37·3	1885	22·0	40·2
1855	29·1	33·9	1888	21·2	36·9
1858	26·3	38·5	1890	23·1	41·4

If the death rates given in this table be compared with the average temperature of the period, it will be seen that there are other influences at work, apart from temperature, affecting disease and producing death, and it may be said with reference to these observations, that up to the year 1875 the

[1] This is shown in Plates 1 and 2.

mortality of England and Wales in any quarter of the year (with the exception of the September quarter of 1849, when cholera was rife[1]) was at these particular periods of low water greater than at any other time.

It is well known that heat and cold limit the area of particular diseases, and that the temperature of the ground has also an essential bearing on the causation of disease. Heat has also a tendency to reduce ground water, and, on the other hand, intense cold has a similar effect, as in time of frost the surface waters are frozen and percolation is stopped.

In the study of this question, we must also bear in mind that the amount of light has a material effect on disease. The healthiest months of the year are those in which the sun is for the shortest period below the horizon; the unhealthy periods are those in which there is the longest period of darkness. It has been well said that "pestilence walketh in darkness," and this is undoubtedly true, for, at present, we know but little of the causation of disease. The period of greatest darkness is also that of the greatest amount of percolation of water through the soil, as it is found that many diseases increase during the percolation period and decline as percolation ceases, so that there is a parallelism between the periods of darkness and percolation. It is well known that in malarious countries, malaria is most active at night, and districts which can be traversed with impunity in daylight become dangerous after sunset. We have also the experience furnished by Arctic Expeditions. H.M.S. *Assistance* was 94 days in winter darkness in the Arctic regions in the Expedition of 1850-51, and when the health of its crew is compared with that of the *Alert*, in the last Arctic Expedition, which was 142 days in polar darkness, it was found that scurvy was very much more rife in the ship the longer exposed to the influence of darkness, although both vessels were on an equality with regard to provisions and other matters.

Dr. Macnamara has observed in India that cholera cases were always most numerous when the sky was overcast, and in this country it has been observed that more deaths take place while the sun is below the horizon than when it is above the horizon. We must, therefore, in studying this question make allowance for the periods of darkness, and must eliminate this as a probable source of error in judging of the influences of ground water. When the question of epidemic disease is studied, it will be found that the black death of the 14th century, the sweating sickness of the 16th century, the plague of the 17th century, and in modern times cholera, typhoid fever, scarlet fever, dysentery, diphtheria, all follow the same track, having the same seasonal fluctuations. We may, therefore, look to some common cause favouring the development of these particular diseases.

In studying the question of disease, we must also bear in mind that the conditions which affect mankind also influence the health of cattle. When this is more generally known, probably greater attention will be paid to the means of preventing loss amongst the stock of the country, even if the health

[1] I am not certain that in these years the population of the country was not over estimated, and that it consequently appears to be more then was really the case. The ground water was certainly not so low as in other years given in this table.

of man is neglected, for it is curious in an enlightened country like England, in which sanitary science has had its origin, that a Minister of Agriculture, who looks after the health of the cattle, should be appointed before we have a Minister of Public Health for the population.

Disease is undoubtedly more potent and strongly marked amongst the young. Now it would be impossible in the course of such a paper as this to draw attention to the influences connected with every disease. I, therefore, only propose to direct your attention more particularly to what are known as zymotic diseases, the general death rate, and the mortality of children under 5 years of age.

The question may be asked, What is ground water? The answer is, All water which is found in the surface soil, except such as may be in chemical combination with the materials forming the crust of the earth. It is mainly derived by percolation from rainfall; the ground becomes wetted, and when fully saturated in porous soils, water passes through and lodges in the lower portion of the strata and becomes the free water which we measure in wells in order to ascertain its relative height from time to time. Ground water is also produced by condensation: whenever the ground is colder than the air, a certain amount of vapour is condensed within the pores of the surface of the soil, and this is partially given off at those times when the soil is warmer than the air, especially at night. In dry countries ground water is principally supplied by the infiltration from rivers, as for example in the Delta of the Nile. In some strata, the whole of the ground water is held by capillarity, as in clay and other soils and in rocks of close texture, whilst in others it is held both by capillarity and as free water, and this ordinarily is termed the ground water. The free ground water may be increased by water passing from the superincumbent strata, in which it is held by capillarity, even without rain, as in the case of a rapid fall of the barometer. The free water of the ground is a very active agent, and may become the direct vehicle for conveying to unlimited distances the active properties of disease. This free ground water rises and falls, as a rule, every year, forming a wavelike profile, when plotted as a curve, the rise being much more sudden than the fall. It is also always moving in particular directions. As a rule it moves in the direction of natural outlets, which may be either the sea, springs or rivers; its greatest amplitude of fluctuation is at the most distant point from its point of escape, while its least range of fluctuation is close to the point of discharge. As a rule, when there is a large quantity of water in the ground a large quantity is discharged, and *vice versâ* with small quantities. It should be noted that most of our old cities and towns are located upon porous soils in which usually there has been water in the subsoil. This has, no doubt, been often done as a matter of convenience for the water supply, and in those periods when such underground waters were exclusively relied upon to furnish a supply of water to the inhabitants, epidemics and diseases of various kinds were very much more rife and fatal than at the present time, when in the principal towns of the country such sources of water supply have been abolished. The mechanical effect of rain passing into the ground has

also an influence in disseminating disease, because the ground always contains air, and the rainfall cannot occupy the space previously occupied by this ground air without expelling it. This air more readily escapes into our houses, the porous passages to which are left open, being protected from the influence of rain, while those outside the house are sealed by the falling rain. On the other hand, all the time that the ground water is diminishing there is a tendency for air to be drawn in to occupy the space formerly taken up by the water. Upon investigation, it will be found that diseases of a certain type are most rife during the period that the ground is filling up with water and expelling the ground air, and are least prevalent when the current of air is inwards instead of outwards from the ground. Of course these conditions are also subject to variation with the changes of barometric pressure. As a rule, the amount of free water in the ground cannot with accuracy be estimated by the quantity of rain, as the quantity entering the ground depends upon its hygrometric condition; however, in the absence of other information, the state of the ground water may be often inferred from rainfall records. In some years it is found that the actual amount of rain which may enter the ground at a particular period, as measured by percolation gauges, may be considerably less than that flowing off; for if the ground waters are very low, probably more will enter the ground than flow off in the same year. As an example, in the year 1888, after the low waters of 1887, but 7 ins. were known to have flowed off the Croydon Drainage area of the River Wandle, while over 18½ ins. percolated through a chalk gauge in the same year. Again, in the year 1887, only 5 inches of rain passed through the percolating gauges, while in that year nearly 9 inches flowed off, the balance being drawn from the store previously left in the ground. In some years there is no low water, but these are exceptional periods. However, the records from a well at Hartlip Place, near Sittingbourne, show that in the year 1829 there was no low water, the water rose all through that year up to June 1830, and this was a healthy year. In some districts, the fluctuation in the ground water has considerable amplitude. It is not unusual to find wells in which the water line may within a few months vary over 100 feet between the highest and lowest levels. On the other hand, in certain seaside places and towns located near rivers the fluctuation is very small, and as a rule the healthiest districts are those where there is the least vertical rise and fall of the subsoil water, and this is the case in nearly all seaside health resorts. There are also examples when an undue elevation of the free ground water, beyond what is ordinarily its normal range, may produce all the effects which are noticeable after low water periods. Professor Pettenkofer, in his observations at Munich and elsewhere, established beyond doubt the coincidence of cholera and typhoid fever with low ground water. If we direct our attention to American experience, we find the Reports of the State Board of Health teeming with information upon this very point, and Dr. Draper says with reference to Massachusetts, that the charts show that enteric fever, cholera, diarrhœa and dysentery, are more prevalent when springs are low than at other periods of the year. Investigations conducted by Dr. G. Buchanan

and Mr. W. Whitaker, F.G.S., in 1867, on phthisis in this country,[1] show that an excess of water in the soil increases the death rate from that disease. It may be said with regard to all the epidemics of typhoid fever in this country that, without exception they occur immediately after the periods of the lowest water, and as a rule typhoid fever occurs at periods of the year when the waters are generally low, and on the rise of the water, usually in the autumn.

We know that the germs of disease can be carried a considerable distance underground through the soil by the movement of the free ground water, as shown by the experience at Lausen in 1872. I can also point out a case in my own experience in a chalk district in Yorkshire occurring within the present year, where polluted water has travelled underground a considerably greater distance than in the case of Lausen, and has produced typhoid fever.

In some districts, the number of disturbances or rises and falls in the subsoil water have a marked influence upon health; for example, if the health statistics of Chichester are compared with the long record of the well at Chilgrove near that city (the observations in connection with which have been carried on by Mr. Thomas Wood and his father), it is found that the greater number of disturbances which have occurred in the Chilgrove well mark the most unhealthy years within the city of Chichester. The year 1888 may be taken as a recent example, when there were three distinct rises and falls in the water of this well in this particular year, and the proportional mortality in Chichester was the highest recorded in the last 20 years.

That the earth itself does exercise a baneful influence on health has been well exemplified by the statistics referring to the unhealthiness of cellar dwellings, which have also established the fact that ground floors, as a rule, are not so healthy as the upper rooms of our habitations.

The absence of water passing into the ground for a long period naturally leads to the lowering of the free ground water line, and may lead to the drying of the ground above the water line; and it is curious to note with reference to small pox that the periods preceding such epidemics of small pox are those in which there has been a long absence of percolation and consequent drying of the ground. On the other hand, small pox is unknown at periods when the ground has never been allowed to dry, or is receiving moisture by condensation or capillarity. The nature of the soil affects the results, as in percolating gauges it is found that all soils will not record the particular conditions of dampness which are favourable to some diseases.

It should also be noted with reference to the effects of ground water upon disease that these conditions may be often artificially produced. It is curious to note in the first epidemic of typhoid fever in Croydon in 1852, that previous to its outbreak the ground water had been artificially lowered under the town 6 feet by the destruction of a mill dam and the construction of a subsoil drain for the express purpose of lowering the ground water, and it is also curious to note that Dr. Neill Arnott, who reported upon this particular epidemic at Croydon, gave, in his report, an instance which occurred in the

[1] "Report by Dr. Buchanan on the Distribution of Phthisis as affected by dampness of the Soil." *Tenth Report of The Medical Officer of the Privy Council*, 1867.

year 1825, where, after the construction of a sewer and the drying of the ground, which was marked by the drying up of the ponds in its particular neighbourhood, an outbreak of typhoid fever occurred. It is a matter of common experience that in all old towns formerly ramified with cesspools, and often deriving their drinking water from local wells, it is not at all infrequent when works of drainage are first introduced having a tendency to lower the subsoil water, for typhoid fever and other diseases to occur, and this is not unusually ignorantly attributed to the new system of sewerage.

We possess in this country a number of records with regard to the height of the ground water, and these records are multiplying yearly, so that probably, when the importance of this question is more appreciated, we shall have a further increase. The registration of deaths in this country only commenced in July 1837. We have in many parts of the country complete records of underground water which carry us back beyond the date when registration of deaths commenced, and by comparing the records which we now possess with the registrations of deaths, we are able to show that the relative height of the ground water has a material bearing on mortality. It would be impossible, in the limits of an address of this kind, to particularise all the various diseases which are influenced by underground water. I trust the information about to be given will furnish some useful material to any person desirous of studying its influence on any specific disease. I may, however, point out to those who are ignorant of the fact, that an investigation of this kind has been made in the case of London and New York by Dr. Buchan, and Sir Arthur Mitchell, M.D., and the published diagram of London mortality shows at a glance the incidence of every class of disease which has occurred during a period of many years. It will be apparent to any one who will study this document that certain diseases have their allotted seasons and conditions under which they are more or less rife.

The study of underground water shows that certain diseases are more rife when the water is high in the ground, and others when the water is low. The conditions that bring about and accompany low water, however, have by far the most potential influence on health, as all low water years are, without exception, unhealthy. As a rule, the years of high water are usually healthy, except that it often happens when high water follows immediately upon marked low water, that on the rise of the water an unhealthy period follows. This has been already referred to and pointed out in the tables, which show the very high death rates in the first quarter of all years following marked low water periods. The most unhealthy periods are those which indicate the first passage of water through the ground. Periods such as these are indicated by Dr. Arbuthnot, when he wrote "The surface of the earth being by drought first shut up and afterwards opened by rain." He also pointed out what is found to hold good in modern times, that the breaking up of frosts was followed by the commencement of epidemic disease, and he specially mentions the conditions previous to the plague of London as being very singular, in a sudden thaw, breaking out after a hard winter frost, lasting till nearly the end of March, and the ground covered with water from melted snow, while ice and great heat succeeded.

Many epidemics, especially of cholera and typhoid fever, have been traced to particular rainfalls. The remarkable correspondence between rainfall and fever is shown by the diagrams of the outbreak of typhoid fever in Paris in 1882. The majority of the zymotic diseases follow the period of percolation and are most rife in the year of lowest water.

Low water years are also as dangerous to cattle as to man. The year 1714 was a remarkably dry year, when only 11·19 inches of rain were recorded as falling at Upminster. In that year the burials in Croydon were more than double those of the preceding year, and in London the burials rose from 21,057 in the preceding year to 26,569 in this particular year. Another dry year was 1742, when 15·7 inches of rain were recorded at Lyndon. In that year the burials in Croydon were almost three times as numerous as in the following year, whilst the burials in London were 32,169 as against 27,483 in the following year. In both these years much cattle died from murrain.

There have even been greater periods of drought recorded than in the years mentioned; and without exception they have exercised a baneful influence, so, in modern times, the periods of drought mark the periods of disease. On the other hand, wet summers are usually healthy. Those years in which there has been no low water are those in which health has been invariably good. In the year 1829 the records of the well at Hartlip Place show that there was no low water at the usual period in that year. The waters rose continuously through the year up to June 1830, and so, too, with other years in modern times, such as the years 1860 and 1879 when a similar state of things existed, and these are all healthy periods.

We must also bear in mind, in studying these questions, that the rates of mortality are, by no means, so reliable as the rates of sickness. Unfortunately, however, in this country we have not the rates of sickness at present available. In Japan, however, there is every year recorded both the number of cases arising from certain zymotic diseases, as well as the number of deaths taking place, and as the seasonal variation of temperature in Japan is almost identical with that of our own country, we can observe in that country the influences of climate upon particular diseases. So, also, in countries in which there is a chronic state of dryness, as in Egypt, it is found that the health is materially influenced by the height of water in the ground. A low Nile marks an unhealthy period, and the most unhealthy times occur while the ground is filling up with water. For example, at Cairo, the average height of the Nile for 6 months, from January to June 1888, was 13·83 metres, when the death rate was 43·1; in the same period in 1889 the average height of the Nile was 13·5 metres, and the death rate was 49·1.

It will also be found, in studying this subject, that the districts which draw their water supplies direct from the ground are usually most subject to epidemics, and disease is much more marked there than in districts in which the water supply is drawn from rivers supplied from more extended areas, or from sources not liable to underground pollution. In the case of Croydon one portion of the district (under three-fourths) is supplied with water taken

direct from the ground, whilst the remaining portion is supplied with water from the River Thames. It is curious to note that, even so recently as 1885, the zymotic death rate in the districts supplied with underground water was twice as great as in that part of the districts supplied from the Thames, and in this particular year 41 deaths from small pox occurred in the district supplied by underground water, not one of which is recorded outside that district.

Cholera.

I propose now to deal with the zymotic diseases as affected by ground water, beginning with cholera. Cholera is known to attack with the greatest virulence places of low elevation, the very sinks of impurity. These places have to contend not only with their own local impurity, but with the pollutions which are carried by the movement of the ground water from places at a higher altitude into them. Cholera ordinarily breaks out when there is the least ground water, and a high air and ground temperature is also necessary for its development. As a rule, the low positions are favourable to the production of these high temperatures. Dr. Macnamara says, with regard to cholera, it is more rife in low alluvial soils, and it advances from east to west, or it advances exactly in the direction from the least to the greatest recorded falls of rain, and, as a consequence, just in proportion to the lowness of the ground water, which will be first lowest in the eastern districts and last lowest in the western districts. It has also been observed that cholera follows rainfall. After the drought in India of 1860, followed by rain in 1861, cholera broke out, and it has been observed by Dr. Macnamara and others that rain is connected with the development and dissemination of cholera poison, and that in India no wide-spread epidemic can occur unless during or after rain; but, on the other hand, it has also been noted that excessive rains will remove the disease, probably by rapid percolation and the cleansing of the soil from the germinal matter, or by producing a state unfavourable to the development of the germs. It should be noted, with reference to the epidemics of cholera in this country in 1832, 1847, 1854 and 1865, that these periods were all years of low ground water.

The following table (p. 12) shows the incidence of cholera and small pox in Calcutta for 26 and 29 years respectively.

It is curious to note the marked parallelism between small pox and cholera in India. But this parallelism between these two diseases is not confined to that country, nor to those diseases only. In Japan, where the seasonal variation of temperature occurs at the same period of the year as with us, but has a greater amplitude, they have for six of the zymotic diseases a registration of sickness; and an examination of these sickness returns shows the same results as in India. The second table on page 12 shows the rates of sickness in Japan for a period extending from 1879 to 1887, the population of the country being estimated at a little over thirty-nine millions in 1887.

TABLE SHOWING DEATHS FROM CHOLERA FOR 26 YEARS, AND FROM SMALL POX FOR 29 YEARS IN CALCUTTA.—COMPILED BY DR. MACPHERSON.

Month.	Cholera, Total Number of Deaths.	Small Pox, Total Number of Deaths.	Rainfall.	*Average Temperature.	Range of Temperature.	Prevailing Winds.
			Ins.	°	°	
January	7150	1425	0·21	63·4	17·9	N NE NW
February	9346	2845	0·42	74·2	17·3	N NE NW
March	14710	4934	1·13	82·9	16·3	W SW S
April	19382	4249	2·4	86·6	14·7	S WSW
May	3335	2261	4·29	89·0	13·3	S S W
June	6325	1054	10·1	86·2	9·0	S S W
July	3979	555	13·9	84·0	6·4	S SE SW
August	3440	223	14·4	82·6	5·2	S SE SW
September	3935	188	10·4	83·8	6·6	S SW W NW
October	6211	147	4·72	81·1	8·8	W E S NW
November	8323	132	0·90	75·4	14·2	N NE NW
December	8159	576	0·13	66·9	16·4	N NE NW

JAPAN.—INFECTIOUS AND CONTAGIOUS DISEASES.

Year.	Cases of Cholera.	Cases of Small Pox.	Cases of Typhoid Fever.	Cases of Diphtheria.	Cases of Dysentery.	Cases of Typhus.
Jan. 1879 to June 1880	162637	4799	10052	1280	8169	2341
July 1880 to June 1881	1580	3415	17140	1838	5047	1527
July to December 1881 (6 months)	9389	342	16999	1107	6827	564
1882	51631	1105	19308	2028	4330	629
1883	969	1271	18769	2307	21172	412
1884	904	1703	23279	2237	22702	3459
1885	13824	12759	29504	2798	47377	2302
1886	155923	73337	66224	3265	24326	8225
1887	1228	39779	47449	2741	16149	2487

It should be noted that cholera, as a rule, has not the same monthly incidence as small pox. The question of high temperature, which materially affects cholera, would appear to have, if it has any influence, the contrary effect upon small pox as upon cholera, after the conditions preceding its outbreak have been established. While the general conditions of ground water which bring about cholera also bring about small pox, the climatic conditions that accompany these diseases are of an opposite character.

Small Pox.

The true significance of small pox must be studied probably not so much with respect to our time as to periods gone by, when it was very much more fatal. It is, therefore, interesting to note that Dr. John Arbuthnot stated with reference to small pox, that he found that it was most fatal during hard frosts and cold North-easterly winds. Small pox is always preceded by a long period of dryness of the ground, measured by the absence of percolation. It should be noted that with reference to the year 1871, which was a very fatal

year, the smallest amount of percolation on record occurred. The register at Apsley Mills shows that but 1·36 inches of water passed into the ground in the whole of that year, and so it has been with other years, for, taking the Croydon records, it will be found in the autumn of 1870 small pox commenced in Croydon after a very dry period, and continued up to the autumn of 1871. In 1876 an outbreak again occurred after a very dry period, and continued until the autumn of 1877, and exactly the same conditions accompanied the outbreaks of 1881 and 1882, 1884 and 1885. It is quite clear that small pox only occurs after intense dryness of the ground. Since September 1885 there have been no deaths from small pox recorded in Croydon, but during the whole of that period (5 years) there has been but one month when no measurable quantity of water percolated through a gravel percolating gauge 1 yard deep, and that was in October 1886, a period when the ground was naturally moist; but in 1884, when small pox last broke out, it was preceded by 7 months in that year when no measurable quantity of water percolated through the same gauge. Having regard to the relation which has been shown to exist between small pox and other zymotic diseases which are capable of being transmitted by water and are propagated by unsanitary conditions, it is almost absolutely certain that small pox is propagated and disseminated in the same way as cholera and other diseases under the peculiar climatic conditions to which I have drawn attention.

Typhoid Fever.

The conditions affecting typhoid fever are capable of definite statement. The disease is most prevalent after a dry time when the first wetting of the ground or "percolation from any cause" takes place. The quality of the ground water does not appear to have any influence upon the disease, as shown by Professor Pettenkofer, yet all authorities agree that this is largely disseminated by well and other waters liable to contamination at low water epochs. Typhoid fever is always more rife while the waters are rising in the ground than when they begin to diminish. In the first great epidemic of fever in Croydon, in the autumn of 1852, which occurred with a very rapid rise of the subsoil water, and also after the artificial lowering of the water to which I have already referred, it is established beyond doubt that the waters in this district had been remarkably low. In the 20th Volume of the *Proceedings of the Institution of Civil Engineers*, page 199, attention is drawn to the fact that in this particular year the supply of water in the River Wandle (one branch of which rises at Croydon) was so deficient, that the mills were compelled to be shut down three hours out of every twelve, and that there was still a deficiency of water. The low water periods which occurred in 1854 are well authenticated, for this particular year was universally a low water year. In 1858 there was another low water period, not, however, so low as the year 1854. In 1865 and 1866 there was a further epidemic of typhoid. Preceding this epidemic the Croydon branch of the River Wandle was known to have been absolutely dry, and in 1875 and 1876 was the last great epidemic, when again it was reported that the Croydon branch of the

River Wandle was dry. Since that period no such degree of lowness of the springs has been experienced at Croydon, and the sanitary works executed since that period have, in my judgment, added much to the healthful condition of the place.

I must now direct your attention to the distribution of the cases of fever which occurred in the last epidemic at Croydon, and shall compare them with the conditions which accompanied the epidemic of typhoid fever in Paris in 1882. Dr. Buchanan, in his report upon the outbreak of typhoid fever in Croydon in 1875, gives the distribution of cases throughout each month of that year. The epidemic, however, continued through 1876. The figures of 1875 show that there were two periods within that year when the disease was at maximum intensity, namely, in April—a most unusual period—and in October, the disease occurring in the spring of 1875 at a much later period than that at which the ground waters ordinarily commence to rise. The cause of the outburst at this period of the year is clearly demonstrated, as it occurred on the rise of the ground water, which rise had been delayed to the period when the disease eventually occurred, as is shown by the records of the state of the ground water within the higher portions of the Croydon drainage area, and which show that, after a very low water period, the waters began to rise in November 1874, and were rising up to March 1875, when they fell, rose slightly in June, then fell and rose again between September and October; there was a fall in November and a rise again in December. The following table shows the height of the water in the well at Caterham Lunatic Asylum, located near the head of the Croydon Drainage Area, at the dates given, together with the number of cases of fever occurring in 1875 and the deaths from fever in the three last months of 1874, through 1875 and the four first months of 1876.

WATER LEVELS IN WELL AT LUNATIC ASYLUM, CATERHAM AND FEVER IN CROYDON.

Year.	Date.	Level of Water above Ordnance Datum.	Date.	Reported cases of Fever in Month.	Deaths from Fever at Croydon.
1874	23 October	228·03	October	No record.	—
	5 November	232·53	November	,,	—
	5 December	238·53	December	,,	1
1875	2 January	260·53	January	15	1
	1 February	287·53	February	53	1
	2 March	300·03	March	79	4
	1 April	295·53	April	186	13
	1 May	276·03	May	39	10
	1 June	280·03	June	30	8
	1 July	268·03	July	18	4
	1 August	264·03	August	32	3
	2 September	260·03	September	69	5
	2 October	261·03	October	275	15
	5 November	257·03	November	92	19
	1 December	288·03	December	71	6
1876	1 January	290·53	January	No record.	10
	1 February	291·03	February	,,	9
	1 March	294·03	March	,,	8
	1 April	312·03	April	,,	2
	2 May	304·03	May	,,	—

It should be noted that the water in Croydon itself, which is some miles lower down the valley, would not ordinarily begin to rise until a later period than the waters in this particular well.

In Paris, in 1882, an exactly similar state of things occurred ; an epidemic of fever broke out, as shown by the records published by the late M. Durand Claye, C.E., after a slight rise in the ground water. All the outbreaks of typhoid fever which have been investigated in this country have occurred under similar conditions. As a notable example, the outbreak which occurred at Terling, a village having a population of about 900 persons, in which, between November 1867 and the 13th January 1868, there were 208 cases of typhoid fever. It is mentioned by Dr. Thorne, who inquired into this epidemic, that all the wells in this village had become dry previous to the outbreak of fever, and the disease made its appearance at a time corresponding to the first replenishment of the water in the wells, after being so exceptionally low. Since 1868 numerous recorded epidemics of typhoid fever have occurred, accompanied by exactly the same circumstances as regards the state of the ground water, and all the great epidemics of typhoid fever have occurred in years when the ground water was especially low.

There has been a considerable amount of evidence collected in Paris, and also in this country, showing that outbreaks of typhoid fever can be traced to particular dates of heavy rainfall, and clearly establishing the fact that rainfall is associated with these epidemics. Consequently, we are not surprised to find that there often exists a parallelism between rainfall and typhoid fever. In judging, however, of the effects of rain upon the subsoil, the direct measurement of a well will not give, as a rule, the first indication of the commencement of water percolating through the ground, for the simple reason that if the quantity passing through is very small, it has no appreciable effect upon the height of the water in the ground itself, for the ground water is like a reservoir which at certain periods receives water, but water is also flowing out of it and no increase will be visible in the store until the rate of supply exceeds the rate of depletion. When, however, we do perceive that there is a check in the rise of the waters, or they become stationary, we may conclude that percolation has commenced. It may also be a matter of considerable importance to note that in all the epidemics of fever which have occurred in Croydon the universal testimony has been that women, children, and teetotalers have suffered the most, and in Dr. Buchanan's report on the last epidemic of fever it is shown that out of every 1,000 houses in that part of the district supplied with water taken direct from the ground, 104 were invaded by the disease, but in the district outside this area, containing, at least, a fourth of the whole population of the place, only 7 per 1,000 were attacked.[1] The significance of these facts ought not to be ignored by all who are answerable for the public water supplies of our country.

Diphtheria.

Diphtheria, according to a communication made at the last International Con-

[1] Most of these cases were children attending the Board School at which ground water is supplied from Croydon.

ference on Hygiene at Berlin, like typhoid fever, is propagated by excremental poisoning of the ground, and we know it is disseminated almost in the same way as typhoid fever. We know that it follows typhoid fever in parallel lines, but the very opposite conditions are necessary for its development to those which occur with typhoid fever and small pox. A damp state of the ground, marked by extreme sensitiveness to percolation of rain, is the condition which is essential to the development of diphtheria. With typhoid, a dry ground is essential to development, as we approach one or other of these conditions, so diphtheria or typhoid supervene. Diphtheria follows typhoid in its incidence, and occurs in the percolation periods. In this country, diphtheria has not until recent periods been separately registered, for some years it was registered as a type of scarlet fever ; and we have no record in Croydon of its existence before 1849. Since 1858, however, it has been recorded with some degree of regularity. During the whole of the last 5 years the ground at Croydon has been in a continual state of dampness, as indicated by the records of the percolation gauges, and during the whole of that period diphtheria has been more or less rife, and has been generally increasing throughout the country.

Scarlet Fever.

Scarlet Fever follows the state of the dryness of the ground, which is essential for its development, and it occurs in the percolation period. The conditions that precede small pox are those favourable for the development of this disease. Hence it is most rife in the years preceding small pox. Like small pox the dampness of the ground for any considerable period in any particular locality may check its development, or render it less virulent, but it is most rife in low water years.

Measles.

It is curious to note with reference to this disease that in Croydon it apparently follows the opposite law to that of typhoid fever in the years in which there have been epidemics of typhoid fever, as in 1852, 1864, and in 1875 ; when the conditions were favourable to the development of typhoid, there were no deaths, or very few, from measles. This disorder is least prevalent at the low water periods, and is mostly rife at and near high water periods. In this respect it follows the same course as small pox, and as a rule measles is most rife in a low water year, especially following another low water year.

Whooping Cough.

Dampness of the ground is an essential condition to the development of whooping cough. It is a disease which causes a large number of deaths, and has been particularly rife during the past five years, during which time there has been a marked dampness of the ground. It destroys, in Croydon, three times as many persons as small pox, and it is most rife and fatal in all those years when small pox is absent. It follows the percolation period in its incidence, increasing with percolation and diminishing as the waters in the ground subside.

Diarrhœa.

It is generally supposed that diarrhœa is almost entirely influenced by high temperature. There is no doubt whatever that high temperature has a marked influence in the development and spread of this disease, but by comparing the records of any particular years with the temperature, it must be observed that there are other influences also at work, and it is found that diarrhœa is generally more prevalent in a low water year than in other years, that is, that in a low water year with a very much colder temperature we get a very much higher death rate from this disease. For example, in Croydon in 1854, which was a very marked low water period throughout the country, the average temperature for June, July and August was 59°·4. In the following year, the temperature of the same months was 61°·1. In 1854, the deaths were over five times as numerous from this disease as those which occurred in 1855, very clearly establishing the fact that diarrhœa, influenced as it is by high temperature, is also amenable to the conditions which produce low ground water, and that the organic changes which take place at such periods in the ground affect all sources of water supply, the temperature of which, rather than the season, governs the course of diarrhœa.

Deaths of Children.

Whatever errors may exist as to the cause of death amongst children, there can be no doubt as to the ages at which children die. In comparing the deaths of children under 5 years of age with the state of the ground water, it is found that there is in Croydon an exact parallelism between the state of the ground water and the death rate of such children.

General Death Rate.

It should also be noted that the general death rate of a district is regulated by the state of the ground water, in the same way as the deaths of children, but in a less marked degree. Years of drought and low water are always found to be the most unhealthy.

In concluding this subject, I desire to impress upon you that the health of communities is influenced by the sanitary conditions under which they live. Diseases of a virulent type are producible by very opposite climatic conditions, but are always most rife and most fatal in those districts in which there is the greatest chance of the ground being polluted. It is essential for the conditions of a healthy life that the soil upon which we reside should be freed from all chance of pollution, and every step should be taken in this direction. In studying the causation of disease it is also important that very much more attention should be paid to matters referring to the hygrometry of the soil. One would like to see a considerable extension made in establishing percolating gauges, and that all Meteorological Observatories should possess such an instrument.

It is also essential, in the study of the cause of disease, that the registers of sickness, which are now required to be taken in many of our towns, should

be published in ample form every year by some authority, and should be available for the use of all investigators. I trust that what I have said may be of interest, and may be the means of getting enlisted into our ranks a larger number of observers, particularly those who can devote their time to the elucidation of the various meteorological conditions which affect the health of the nation.

NOTE ON A LIGHTNING STROKE PRESENTING SOME FEATURES OF INTEREST.

By ROBERT H. SCOTT, M.A., F.R.S.

[Received November 17th.—Read December 17th, 1890.]

On my recent visit to the West of Ireland, I learnt that a remarkably violent lightning stroke had occurred within the peninsula of the Mullet, in the barony of Erris, Co. Mayo, and I went to the spot to collect what information I could.

The occurrence took place January 5th, 1890, in a violent storm of wind. I did not visit the place until October 12th, so that I have for the most part only hearsay evidence to report. The locality is the fishing village of Tip, about one mile from Ballyglass Coastguard Station, on Broad Haven. The house struck belonged to Michael Moran, who with his wife were the sole inmates. It is a thatched cottage, one storey high.

At 10.30 p.m. January 5th, 1890, Moran was in bed, his wife was standing up. She heard a very loud clap of thunder, and called to her husband to get up. Immediately after she was struck down and stunned for a short time, a few minutes. The bedroom showed marks of the lightning on the walls in various places.

The next morning it was found that the kitchen adjoining the bedroom was not much damaged, but that the sitting room on the other side of the kitchen had been completely wrecked.

The grate was forced out of its setting and thrown across the room. Various marks were seen on the walls, and a hole was pierced through the wall opposite the head of a crowbar which was leaning against the wall in the adjacent workshop. The hangings on the mantelpiece, &c., were much torn; there were no signs of fire or fusion, except that two corners of a photograph on a metal plate standing on the chimney piece were fused; but the photograph itself was otherwise uninjured. All objects of glass or china in the room were upset, but only a few of them broken; a corner was cut clean off a glass ink bottle, without spilling ink, &c. The most extraordinary occurrence was what happened to a basket of eggs lying on the floor of the room. The shells were shattered, so that they fell off when the eggs were

put in boiling water, but the inner membrane was not broken. The eggs tasted quite sound. Moran's account is that he boiled a few eggs from the top of the basket, the rest were "made into a mummy, the lower ones all flattened, but not broken."

I have referred this latter statement to my friend, Mr. C. W. Boys, F.R.S., whose reply is as follows :—

"I can only conclude from your account of the destruction of the egg shells by the lightning, that the action was purely mechanical, the result of a detonation among the eggs, rather than electrical. I do not think the eggs within would have remained undamaged if the lightning had really struck them.

"It seems very similar to the result of an experiment which I have seen in which an egg thrown up in the air and falling on hard turf, was not broken, though no doubt the shell at the point of impact was cracked up a good deal.

"The egg was not boiled, for on being thrown up a second time, which was not fair, it spread itself about in a way which is not possible with a boiled egg."

Note on the Effect of Lightning on a Dwelling-House at Twickenham, September 23rd, 1890.

By A. BREWIN, F.R.Met.Soc.

[Received December 2nd.—Read December 17th, 1890.]

On the 23rd of September, 1890, my house at Strawberry Hill Road, Twickenham, was struck by lightning, and it may be of some interest if I briefly state what took place. The storm, which lasted a very short time and was accompanied by torrents of rain, came on about 4 p.m., and at 4.15 the house was struck, the flash being accompanied by a heavy crash of thunder.

The house is in a row of detached houses, of the modern Queen Anne's Villa style, all of the same elevation, and there are no tall trees within 150 yards. It is built with double rooms, the two rooms on the ground floor opening into each other with folding doors, which were open. The fireplaces of these rooms are against the outside wall, one above the other, so that there are two stacks of three chimneys each.

The stack to the chimneys of the front rooms was cleft down the outside for some feet, many bricks thrown down to the ground, and the roof broken in two places by the flash, which a neighbour, who was looking out of window at the time, said seemed to separate and strike in several places. Internally

the middle (first floor) room of this front set was the only one affected; everything was knocked off the mantel-piece—an iron one—, but nothing broken; a spring clock knocked flat on its face was picked up going and apparently uninjured. The room was filled with a stifling sulphurous vapour. Two children were in it, and when the servant ran in, the little boy of 6 said his head had been knocked, and the girl of 10 said she "felt all over prickles," a not unnatural feeling if one receives an electric shock. I should mention that, owing to the rain, all the windows were shut, excepting in the back ground floor room. Mrs. Brewin was sitting with two friends in the front ground floor room, and that room was uninjured, though it was below the room, before described, where the children were.

The stack to the chimneys of the back rooms was uninjured, but a rain-water pipe running outside had a piece cut out on a line with the fireplace of the middle (first floor) room. In this room, the tiles of the hearth were lifted, and the carpet near them pushed up, and a heavy china slop pail and water jug standing near the fireplace were knocked together and slightly chipped; there were no marks on the flooring, but there was a hole of about 18 inches diameter made in the ceiling of the room below. At first I thought this was all caused by the concussion on the pipe outside being struck, as no lightning was seen passing out of the back room windows by those sitting in the front; but on taking up the boards there was conclusive evidence that the lightning had entered, as the wires to the electric bells were cut, fused in several places, and the insulating material stripped off them for several feet, and either burnt or pushed back into a heap. All the vases and ornaments on the mantel-piece in the back ground floor room were upset and knocked over, but none broken. The ceiling was found to be so much damaged that it had all to come down.

It is to be presumed that on this, the back side of the house, the lightning came down the chimney of the middle room, passed at the back of the fireplace underneath the tiles, and then through the ceiling, fusing the wires on its way, and out through the open window; but still the water pipe being broken is unaccounted for, as there was certainly no communication through the wall between it and the fireplace. The lightning took no effect on either of the top rooms.

DISCUSSION.

Mr. Blanford drew attention to the fact that the occurrence described by Mr. Scott took place on January 5th, whereas he did not visit the place until October, so that there had been ample time for a certain amount of myth to have become incorporated in the relation of some of the incidents.

Mr. Symons said that the story of the eggs narrated by Mr. Scott, reminded him of the fact that the inside skin, which separated the shell of an egg from the white, possessed a very good meteorological reputation, it having been used years ago for hygrometrical purposes. With the exception of the damage to the basket of eggs, there appeared to be nothing extraordinary in the action of the lightning as described in either Mr. Scott's or Mr. Brewin's paper. The hole knocked in the wall opposite the spot where the crowbar was standing, and the upsetting of articles on the mantel-shelf, were quite ordinary occurrences. These cases of damage served to show the necessity of houses being protected by

lightning conductors. Bells were almost always affected when a building was struck by lightning. As regarded the breaking of the rain-water pipe outside Mr. Brewin's house, it was just possible that the damage might have been done some time previously by the action of frost or otherwise, but remained undiscovered until the thorough examination of premises was made after they were struck by lightning. Rain-water pipes, provided the joints were good, acted as efficient lightning conductors.

Mr. BREWIN said that the piece knocked out of the rain-water pipe was just above a joint.

Mr. WILSON said he understood Mr. Scott to say that the damage to the eggs was due to an explosion in the basket. He would like to know what there was in an egg which was likely to explode. He related a case of a lightning flash in Natal which struck a farm house, when near a powder flask was a pile of new cotton shirts on a shelf. A clean round hole was drilled through the whole parcel of shirts, without any further damage.

Mr. SCOTT said that as there was sufficient electrical discharge to disturb the fire-grate and injure the floor, it was possible that the vibration might have caused the damage to the eggs.

Mr. WHIPPLE suggested that Mr. Brewin should obtain an actual measurement of the electric force necessary to produce such effects as were seen on the bell-wires shown to the meeting. It would also be interesting to ascertain the amount of electrical force necessary to blow a hole in a rain-water pipe.

Mr. TRIPP remarked that there might have been moisture in the rain-water pipe, and if so, the heat of the flash may have given rise to a sudden generation of steam resulting in an explosion and thus damaging the pipe.

Mr. MARRIOTT said that the two storms described in these papers were interesting, as one was a winter storm and the other a summer storm. He had looked at the Weather Chart for January 5th, and found that there was a strong gale blowing at Belmullet, the wind being force 10, and the barometer below 29 inches. The thunderstorm on that day was no doubt due to the passage of a small satellite of the main depression. It was not uncommon to have a thunder-storm occurring to the south or south-east of great depressions.

WIND SYSTEMS AND TRADE ROUTES BETWEEN THE CAPE OF GOOD HOPE AND AUSTRALIA.

By Capt. M. W. CAMPBELL HEPWORTH, F.R.Met.Soc., F.R.A.S.

(Plate V.)

[Received October 15th.—Read December 17th, 1890.]

THE trade with Australia carried on by sailing vessels is still considerable, and although most of the steam shipping in the Australian trade proceeds to Australia by way of the Suez Canal, there are nevertheless a large number of steamships which take the route *via* the Cape of Good Hope. As it is yet a subject for debate as to which is the best parallel for running down the easting between Cape Point, or the meridian of Cape Point, and that of Cape Leeuwin, it would doubtless be in a good cause were modern meteorologists to take up the subject, and by seeking data and inviting discussion, endeavour to arrive at the truth.

In recommending the parallel of 39° S in preference to a higher latitude, that most valuable work, *The Australia Directory*, compiled by Captain C. B. Yule, R.N., and published by order of the Lords Commissioners of the Admiralty, gives the following in a foot note :—

"Although the parallel here assigned of 39° S. as being that where ships may safely run down their longtitude, has been objected to by some writers on the ground that of late years many successful passages have been made in much higher latitudes, some even attaining the 55th parallel for the southern point of their great circle or composite route, still it has been deemed desirable to retain the directions given in former editions of this work, placing before the navigator the grounds for this decision."

"It is true that the distance from the meridian of the Cape of Good Hope to Bar's Strait, or the south coast of Tasmania, is diminished greatly as every succeeding higher parallel of latitude is adopted. For example, the 40th parallel has an advantage over the 38th parallel of 380 miles, or nearly two days' sailing; and again the 45th parallel has an advantage over the 40th to the extent of 650 miles; the 50th over the 45th of 480; and so far, the higher the latitude of the great circle or composite route adopted, the more advantageous is the route in point of distance. But the disadvantages attending the selection of any high parallel should be clearly understood by the seaman, and more especially as regards a passenger ship, or small or ill-found vessel, or one deeply laden."

"Maury, in advocating the higher parallels of latitude, says:—'In recommending this route, which differs so widely from the favourite route of the Admiralty, I do it, not because it is an approach to the great circle route, but because the winds and sea and the distance are all such as to make this route the quickest;' and again, 'The winds to the north of the 40th parallel of south latitude are much less favourable for Australia than they are to the south of that parallel.'"

"The evidence in favour of these opinions as to the winds and seas being more favourable south of 40° appears, however, by no means conclusive; many experienced navigators are of opinion that north of 40° the steadiness and comparative moderate strength of the winds, combined with the smoother seas and more genial climate, compensate by comfort and security the time presumed to be saved by the shorter route made in the tempestuous gales, the sudden, violent, and fitful shifts of wind, accompanied with hail and snow, and the terrific irregular seas which have been frequently encountered in the higher latitudes adopted."

"Independently of the extreme severity of the climate occasionally experienced in high latitudes, there exists the lurking danger of disrupted masses of ice, and icebergs of larger dimensions. The absence of approximate positions of these dangers cannot be depended on for any season of the year; they are, however, rarely encountered north of 40° south, except in the vicinity of the Cape of Good Hope. Between 40° and 45° south, they have been occasionally fallen in with, extending as far as the 65th meridian of E longitude; on the 45th parallel as far as 135° E; and on the 50th parallel extending to 140° E."

I have given the quotation at length because of importance in showing what a wide divergence of opinion existed upon this question between two such eminent authorities; a divergence of opinion which exists at the present time amongst the navigators of the South Indian Ocean.

It is with the object of raising discussion upon this subject that I now bring this paper before the Royal Meteorological Society, and although the data I have collected with a view of arriving at some conclusion upon the subject at issue is of course far too limited for such pretensions, yet I venture to hope they may advance some proofs in favour of the routes usually adopted by me, and which I now presume to recommend. I say "routes" advisedly, because to the parallel adopted in summer with advantage, it might during winter months be inadvisable to adhere.

Through the kindness of Messrs. Wm. Milburn and Co., I have had access to the log books of many of the steamers of the Anglo-Australasian Line, on voyages to Australia *via* the Cape of Good Hope, of which, in addition to those voyages I have myself made between the Cape and Australia, I now submit a brief abstract, dealing of course with those portions only which appertain to this subject.

In this abstract and the accompanying diagram which has been drafted by me for this purpose, there is roughly given the direction and force of the wind; when necessary, the direction and disturbance of the sea, and the state of the weather experienced in the latitude of each succeeding interval of ten degrees of longitude between the 20th and 140th meridians of east longitude, in a line devoted respectively to each steamer whose log has been summarised. These log books have not been selected; those which are not of my own voyages have been taken haphazard from amongst a large collection.

In most cases the recorded force of the wind will probably be under-estimated; as when a vessel is running at a high rate of speed before the wind, the observer is apt to undervalue it, not taking sufficiently into consideration the modifying effects resulting from the onward progress of the ship. The direction of the wind also, as given, is doubtless subject to some error, arising from the aberration caused by the onward progress of the vessel. The disturbance of the sea may in some cases be exaggerated or under-estimated, according to the trim of the vessel on which the observation was recorded, and *ergo*, her behaviour in a seaway. Absolute accuracy therefore is not claimed for these abstracts.

My own experience and information, gleaned in conversation with other commanders of vessels navigating the South Indian Ocean between the Cape and the Australian Colonies, led me some years ago to the belief that the best parallel on which to run down the longitude would be between the 41st and 42nd parallels during winter months, and between the 45th and 46th parallels during summer months. Additional observation, and the perusal of the log books of steamers proceeding between the Cape and Australia, have considerably strengthened this belief.

It is well known that the steady flow of Westerly winds in the South Indian Ocean is interrupted, occasionally during summer months, and frequently during winter months, by gales of cyclonic or semi-cyclonic origin.

The centres of these atmospheric disturbances appear to travel to the eastward, usually—east of the 30th meridian—on paths south of the 43rd parallel during the winter months, and south of the 46th parallel during summer months. Such being the case, in order to keep on the left hand, or westerly side, the most favourable route for vessels coming within their influence would appear to be somewhat to the northward of the 42nd parallel in the former, and somewhat to the northward of the 46th parallel in the latter months; the navigator, by taking this route, would thus make the utmost use of these strong fair gales, whereas by adopting the more southern route, there would be a probability of approaching the centre of the depression, or experiencing the adverse winds on the right of its centre.

These systems of low atmospheric pressure frequently travel to the eastward, for days, at so low a rate of speed that a full powered steamer running on the left-hand side of these centres will often keep up with them for hundreds of miles, sometimes overtake them, and not unfrequently leave them astern. In July, 1887, the s.s. *Port Pirie* ran on the left front of such a system for upwards of 1,200 Admiralty knots, or nearly 1,400 statute miles, and would in all probability have continued under its influence for hundreds of miles more, had she continued her onward progress; but having been stopped and hove-to under canvas in order to effect some repair to machinery, the trough of the depression within three hours passed the ship; the wind, during a hard squall of wind and rain, flying to the West-south-west, and afterwards veering still more to the Southward. The *Port Pirie* had been making about 300 Admiralty knots per day, while in company with this system. This instance is cited, because the position of the ship relative to the centre of the disturbance could be localised from time to time by the appearance of the sky, the veering and backing of the wind, and the oscillations of the mercury.

In May, 1888, the s.s. *Port Victor* encountered a low level cyclone in lat. 38° S., long. 25° E., which she evidently overtook when running to the south-eastward. She appears to have crossed the centre, and was then hove to; when the cyclone passed to the south-eastward. The wind having moderated, continuing her course to the south-east, the vessel again overtook the system, and running to a position north-eastward of its centre, or on its left front, was again hove to, this time for twenty-four hours.

In January, 1889, the s.s. *Port Pirie* overtook a cyclonic disturbance travelling to the east-south-east in lat. 45° 30′ S., long. 44° 2′ E, and appears to have fallen in with the steep gradients in rear of its centre. With the wind at South-west, she ran to the north-eastward, and would doubtless soon have run out of the sphere of its influence, but encountering the inevitable westerly sea, she had to be hove-to, in order safely to combat the dangerous cross sea.

Yet another instance may be cited here. In July, 1890, the s.s. *Port Adelaide* encountered a cyclone. She first came under its influence in lat. 37° S., long. 17° E., when steering to the south-eastward. The Westerly wind which had been experienced since the trades were lost in 26° S. had died away, and a breeze had sprung up fresh from south-east with falling mercury. Skirting the system on the edge of its right side, the vessel crossed its right front, the wind veering through East to North, and increasing rapidly.

The cyclone which up to this time would appear to have remained almost stationary, now gained on the vessel, and the wind at North-west blew a strong gale in lat. 39° 30′ S., long. 22° E.

From this position to the meridian of 36° E. in the same parallel, a strong to whole gale was experienced veering and backing between West-north-west and West-south-west, according as the disturbance gained or lost on the position of the steamer. The wind then backed to North-west, and

freshened with a fast falling barometer, and very ugly appearance; the sea rapidly increasing. The vessel was hove to, *i.e.* brought with her head to the sea, the engines going dead slow. For about an hour after noon—the vessel having been hove-to at 6 a.m.—the wind was moderate, the mercury still falling. Then a furious gale with squalls of hurricane force, accompanied with a tremendous sea was experienced for fourteen hours, the wind veering gradually to South-west, at which point it commenced to moderate.

Many vessels which, in winter, have proceeded to the eastward south of the 42° parallel, have experienced some Easterly winds, presumably from having been on the right side of the centre of areas of low pressure; at any rate there is strong evidence for the supposition that the lower the latitude the less chance there will be of encountering an Easterly wind. North of the 42nd parallel an Easterly wind has not been met with, in my experience, between the 80th and 120th meridian of East longitude.

The winds on the right hand side of the depression which traverse the Southern Ocean are found usually to be moderate; the gradients, it may be presumed, being slight, owing to the permanent low pressure lying to the southward. However, the s.s. *Port Pirie* in the month of June, 1889, in latitude 43° S. and longitude 85° E., encountered a very heavy gale from the North-east, there being every indication that she was at the time on the right front of a cyclonic system.

Although it is probable that the force of the wind, in most cases, will not be found to be greater near the centres of these systems, a near approach to them is to be avoided; for instead of the steady gale and even sea experienced well to the northward of them, a dangerous cross, or confused, sea would be encountered, and in consequence of the greater incurvation of the wind near the centre on the left front, its direction would be North, or even North-north-east, instead of North-north-west or North-west, on their approach, and the shifts of wind would be very sudden.

The synopsis deduced from the survey of the log books which I have summarised tends towards proof of the exemption from Easterly winds, and the comparative moderate strength of the gales north of the 40th parallel.

According to the newspaper report, the s.s. *Damascus* in August 1890, experienced Easterly winds from the Cape of Good Hope to the meridian of Cape Leeuwin, the 44th parallel being adopted for running down the longitude.

In July 1886, the s.s. *Port Pirie*, running down the easting in the 39th parallel, experienced nothing but Westerly wind, while the s.s. *Port Phillip* in the 43rd parallel was encountering a succession of Easterly winds at the same time.

My abstract shows that during the months of April, May, June, July and August, in the parallel of 42° S., and north of this parallel, three Easterly winds have been experienced in six voyages; south of this parallel nineteen Easterly winds in seven voyages; that during the months of January, February and March, in the 44th parallel, and north of this parallel six Easterly winds were experienced in three voyages; south of this parallel three in two voyages. The Easterly winds thus noted have lasted from twelve to forty-eight hours.

Month.		Steamers.	Highest Lat. S.	Gales. Force 8 to 10.	Gales. Force above 10.	No. of Easterly Winds between Long. 20°-120° E.
January	1887....	Port Pirie	46°	2	0	0
,,	1888....	Hankow	39	0	0	0
,,	1889....	Port Pirie	45½	0	1	3
February	1887....	Port Pirie	44	0	0	3
March	1888....	Port Darwin..........	41	2	0	3
April	1888....	Port Denison	45	1	0	0
May	1887....	Port Adelaide	43	0	2	0
,,	1887....	Port Jackson	44	3	0	7
,,	1888....	Port Victor	42	1	2	0
,,	1889....	Port Victor	44	1	0	4
June	1889....	Port Pirie	44	1	1	5
July	1886....	Port Pirie	39	3	1	0
,,	1888....	Hankow	37	5	0	0
,,	1889....	Port Darwin	42	2	0	2
,,	1890....	Port Adelaide	42½	2	1	1
August	1887....	Port Pirie	41½	3	0	0
,,	1888....	Port Phillip	45	3	0	2
,,	1889....	Hankow	39	2	0	1

Should but a general idea of the usual track of the centre of these systems of low pressure be ascertained for each season of the year, such information would be invaluable to the navigator in the "roaring forties" of the Southern Ocean.

In fourteen voyages on which the easting was made in parallels south of 40° S., ice was once only met with; on many of these voyages the easting was made south of the 44th parallel.

DISCUSSION.

Mr. Blanford said that Capt. Hepworth's paper was of great interest. The storms noticed were, of course, not those tropical storms which formed the field of Mr. Meldrum's work, but appeared to be similar to those in the Northern Hemisphere which cross the Atlantic between the United States and the shores of Europe.

Mr. Scott said that he had been much interested in listening to Capt. Hepworth's paper, but thought that his experience of ice had been extremely fortunate. The July track recommended by Capt. Hepworth lay in 'blue water,' as shown on the Admiralty charts, where there was not much danger from ice, but the route recommended for January traversed that part of the ocean which the Admiralty charts showed was dangerous on account of floating ice. January was the month when the ice broke away from the South Pole, and came down into a lower latitude. He inquired if Capt. Hepworth knew how many ships belonging to the New Zealand Company had been reported as missing, probably owing to collision with ice, during the last five years.

Capt. Hepworth said he advocated the parallels of 45° and 46° as the best route, because in his experience ice had not been met with. Of course ice was more likely to be encountered in these latitudes than in a lower latitude, but the danger was very slight. He believed the ships of the New Zealand Company went much further south than 46°, and were therefore more likely to encounter ice.

Mr. Bayard said he presumed that as the Antarctic regions were so much

colder, the ice did not break away so soon or to so great a degree as in the Arctic regions.

Capt. Hepworth remarked that he recommended a higher southern latitude for the summer months on account of the more favourable winds and weather. He had not taken the question of ice into consideration, as he had never encountered any.

Capt. Wilson-Barker said that he had been in the region referred to by Capt. Hepworth, and had generally run down the longitude at about the 42nd parallel. He had never seen ice. The question of the best trade route between the Cape of Good Hope and Australia was very important, but he thought it was a matter which could not be satisfactorily settled without studying the areas of barometric pressure outside the district traversed.

Lieut. W. F. Caborne, R.N.R. (on being called upon by the Chairman), said that, having arrived late, he had not had the advantage of hearing the paper read, and, therefore, was not in a position to make any remarks upon it calculated to be of interest or value to the Society; however, he had had a certain amount of experience in the region under discussion some years ago, and had never encountered ice between the Cape of Good Hope and the meridian of Melbourne, although he had upon one or two occasions travelled along a rather southerly route.

Capt. Maclear wrote to say that he could not be present at the reading of the paper, but having studied it and the diagrams, he considered that it confirmed the Admiralty sailing directions in recommending the parallel of 39° to 40° S. as desirable generally for ships to run down their longitude.

REPORT ON THE PHENOLOGICAL OBSERVATIONS FOR 1890.

By EDWARD MAWLEY, F.R.Met.Soc., F.R.H.S.

[Read December 17th 1890.]

All the observers in 1889 have again sent in returns this year. The observations from Usk were, however, not sufficiently numerous to allow of their tabulation. Returns have also been received from Mrs. Green, Claughton, Caton, Lancashire, and from Mr. J. Hopkinson, the Grange, St. Albans, Hertfordshire.

In order to test the relative accuracy of these returns, I have drawn curves to represent the dates of first flowering of the fourteen plants whose names are printed in bolder type on the list. These curves, when compared with those drawn for the previous year, come out in nearly every case somewhat smoother. From this it may reasonably be inferred that the observations have, as a rule, been made during the past twelvemonth with greater care. This I am very pleased indeed to find. Nevertheless there still occur here and there discrepancies in the records which are very difficult to understand. I will, however, say no more on this point, for with such a small number of returns, it is almost impossible to pick out with any certainty, from among the trustworthy observations, those which have not been made in accordance with the instructions issued by the Society.

LIST OF OBSERVERS.

District.	Station.	County.	Observer.
A.	Babbacombe (Torquay)	Devon	E. E. Glyde
,,	Tiverton	Devon	Miss M. E. Gill
,,	Westward Ho (Bideford)	Devon	H. A. Evans
,,	Wells	Somerset	The Misses Livett
B.	Killarney	Co. Kerry	Ven. Archdeacon Wynne, M A.
,,	Wicklow	Co. Wicklow	The Misses Wynne
C.	Pennington (Lymington)	Hants	Miss E. S. Lomer
,,	Buckhorn Weston (Wincanton)	Dorset	Miss H. K. H. D'Aeth
,,	Salisbury	Wilts	W. Hussey and E. J. Tatum
,,	Swanley (Dartford)	Kent	C. H. Hooper
,,	Ealing	Middlesex	A. Belt
D.	St. Albans	Herts	J. Hopkinson
,,	Oxford	Oxford	F. A. Bellamy
,,	Northampton	Northampton	H. N. Dixon
,,	Thurcaston (Leicester)	Leicester	Rev. T. A. Preston, M.A.
,,	Belton (Grantham)	Lincoln	Miss F. H. Woolward
,,	Macclesfield	Cheshire	J. Dale
,,	Hodsock (Worksop)	Nottingham	Miss A. Mellish
E.	Tacolneston (Wymondham)	Norfolk	Miss E. J. Barrow
F.	Settle	Yorkshire (West Riding)	S. S. Burlingham and The Misses Thompson
,,	Claughton (Caton)	Lancashire	Mrs. E. J. Green
H.	Tynron	Dumfries	J. Shaw
I.	Durham	Durham	H. J. Carpenter

The Autumn of 1889.

During the first half of September the weather was dry and quite summer-like in temperature, thus allowing the harvest to be completed under exceptionally favourable conditions. After this time until the end of October there seldom occurred either a warm or dry day. November proved on the whole very mild, but towards its close there were several keen frosts which gave vegetation its first decided check. Both wild and garden flowers were unusually plentiful, but suffered a good deal from the rains of October and the frequent fogs and humid atmosphere of the last month of the season. Owing to the same causes and the deficiency of clear sunshine, the wood of fruit and other trees had become only moderately ripened by the end of the autumn. The autumnal tints are reported by several observers to have been unusually fine. During November the weather in the West of Scotland was more unseasonably mild than in any of the other districts.

Observers' Notes.

SEPTEMBER 1889.—*Babbacombe* (A.). Streams low. *Salisbury* (C.). 17th. Dahlias killed in a nursery garden near the river. *Hodsock* (D.). Trees began to change colour suddenly quite at the end of the month. *Claughton* (F.). 21st to 23rd. A very sharp and early frost destroyed all the dahlias and tender garden plants.

OCTOBER.—*Babbacombe* (A.). Sycamore defoliated. *Pennington* (C.) The lime and ash had lost all their leaves by the end of the month. Autumnal tints very fine. 23rd. Large flocks of green plover seen. *Claughton* (F.). 7th. A severe storm brought down a great many leaves from the trees. 13th. The woods still very lovely with their varied tints. Hips very plentiful, haws less so.

NOVEMBER.—*Babbacombe* (A.). Autumnal tints very fine in early part of month. Trees defoliated as follows. 1st. Horse chestnut. 5th. Wych elm. 11th. Common poplar. 22nd. Elm. 25th. Beech and all other deciduous trees. *Pennington* (C.). Birds singing up to 26th.

The Winter of 1889-90.

The first winter month was changeable in temperature, but on the whole rather cold. There occurred but little rain, and the duration of bright sunshine was small even for December. In the West of Scotland, however, the weather still continued remarkably mild, primroses and wall-flowers remaining in flower in sheltered places throughout the month. January proved exceedingly mild, the night temperatures especially being everywhere singularly high. Although rain fell at frequent intervals and in excess of the average, there was a satisfactory record of sunshine. Many wild flowers were here and there to be found, and vegetation generally was very forward for mid-winter. The average date of the first flowering of the hazel, taking all the stations, was January 15th, which, for the same stations, is a month earlier than in the previous year. February, in complete contrast to January, was more like a typical March, being cold, dry and sunny, with a great prevalence of Easterly winds. This was a splendid month for working the land, and kept the wheat and other crops well in check. In fact all vegetable growths may be said to have remained throughout it more or less at a standstill. The scarcity of Holly berries was one very noticeable feature of this winter.

Observers' Notes.

DECEMBER 1889.—*Babbacombe* (A.). Many flowers in bloom. *Pennington* (C.). Primroses used for Church decorations. Holly berries scarcely to be found anywhere. *Claughton* (F.). Total absence of Holly berries.

JANUARY 1890.—*Babbacombe* (A.). Vegetation forward, many flowers in bloom, and birds singing throughout the month. Nasturtiums still green. *Pennington* (C.). Several of the forest trees budding and honeysuckle in leaf. *Buckhorn Weston* (C.). The grass has already begun to grow, and here and there the hedges are bursting. *Ealing* (C.). 26th. Saw a Rhododendron in flower in Kew Gardens. *Thurcaston* (D.). A very forward month. 8th. Aconites in flower. *Hodsock* (D.). Hazel and Snowdrop earlier than in any year since I began observing in 1883. *Tacolneston* (E). Song of lark, robin, and both song- and missel-thrushes frequent. Great tit heard.

FEBRUARY.—*Usk* (N.). 13th. Noticed sandpipers about the river here for the first time. *Wells* (A.). Vegetation very forward at end of month. *Pennington* (C.). Birds active and full of song at the beginning of the month, but more quiet as the colder weather came on. 28th. Peach and Nectarine in blossom. *Ealing* (C.). Found Hazel and Coltsfoot earlier than I ever remember. *Northampton* (D.). Extremely unfavourable to the progress of vegetation. 22nd. A Daphn Mezereum in full blossom. *Thurcaston* (D.). Everything at a standstill, I do not remember all plants so long stationary. *Tacolneston* (F.). During the last fortnight all growth stopped by cold winds.

The Spring of 1890.

At the beginning of March there occurred a series of frosts of very exceptional severity. Over a great part of England lower temperatures were then recorded than at any time during the preceding winter months. As shown by Mr. C. Harding in his paper[1] "On the Cold Period at the beginning of March

[1] *Quarterly Journal*, Vol. XVI. p. 152.

TABLE I.—DATE (DAY OF YEAR) OF FIRST FLOWERING OF PLANTS, 1890.

Name of Plant.	A. England, SW.				B. Ireland, S.		C. England, S.					D. England, Midlands.							E. England, E.	F. England, NW.		H. Scotland, W.	I. England, NE.
	Babbacombe.	Tiverton.	Westward Ho.	Wells.	Killarney.	Wicklow.	Pennington.	Buckhorn Weston.	Salisbury.	Swanley.	Ealing.	St. Albans.	Oxford.	Northampton.	Thurcaston.	Belton.	Macclesfield.	Hodsock.	Tacolneston.	Settle.	Claughton.	Tynron.	Durham.
1. *Corylus Avellana*	10	..	..	..	10	14	7	30	10	10	10	..	..	14	20	15	36	4	11	9	..	41	35
2. RANUNCULUS FICARIA	65	27	26	44	11	29	32	11	15	41	..	56	50	71	39	41	75	54	19	74	76	..	70
3. *Mercurialis perennis*	69	27	63	42	..		56	29	16	84	..	67	52	74	82	..	..	54	41	85	29	..	..
4. TUSSILAGO FARFARA	70	51	54	50	53	53	55	50	18	49	..	..	43	53	43	41	44	..	65	8	90	75	64
5. *Narcissus Pseudo-narcissus*	..	55	..	..	36	40	58	..	85	..	71	76	..	85	82	..	74	71	75	..	76	..	..
6. CALTHA PALUSTRIS	79	78	82	72	70	98	85	36	81	..	..	103	86	76	89	94	89	86	93	74	93	116	132
7. *Salix caprea*	69	31	..	65	..	54	33	77	20	74	..	67	76	66	74	..	75	..	72	85	..	..	77
8. ANEMONE NEMOROSA	..	81	82	56	41	76	85	87	57	82	..	79	84	..	80	..	81	85	90	91	90	93	89
9. *Nepeta Glechoma*	79	56	68	79	50	68	90	76	81	41	..	94	85	88	91	97	109	98	86	117	114	120	115
10. PRUNUS SPINOSA	76	83	85	86	29	40	94	92	73	76	..	103	92	82	97	..	105	91	98	88	93	96	104
11. PRIMULA VERIS	88	..	..	88	98	88	110	83	87	..	..	92	..	109	94	102	120	98	80	81	..	..	121
12. *Cardamine pratensis*	114	86	96	80	..	..	85	..	87	..	116	..	..	110	104	..	126	110	..	..	..	113	123
13. *Stellaria Holostea*	91	87	90	100	52	95	73	109	92	..	120	104	112	117	116	132	120	108	90	128	121	119	96
14. SCILLA NUTANS	101	97	118	86	95	106	101	94	87	..	110	104	109	109	104	112	120	108	120	..	109	121	99
15. *Ranunculus acris*	122	116	126	..	130	130	124	109	110	..	119	..	99	134	126	123	138	135	..	139	130	127	..
16. *Veronica Chamædrys*	91	90	90	..	101	106	91	79	85	49	..	109	117	117	124	123	128	119	..	138	..	127	..
17. *Plantago lanceolata*	104	116	98	..	102	81	106	113	94	..	122	117	115	129	117	161	131	117	..	127	..	122	133
18. *Sisymbrium Alliaria*	..	111	109	..	110	116	113	100	101	..	120	..	92	109	115	123	129	107	105	127	125	..	..
19. *Vicia sepium*	138	74	..	113	94	75	134	113	102	..	..	..	136	..	127	..	134	136	120	144	..	132	..
20. *Ajuga reptans*	127	119	130	106	112	..	118	106	122	..	..	..	..	134	127	127	133	124	122	141	123	130	133
21. GERANIUM ROBERTIANUM	102	..	114	91	96	115	119	123	112	..	..	121	122	134	117	134	131	132	122	130	131	133	144
22. *Syringa vulgaris*	120	..	121	119	112	108	116	126	119	..	120	126	122	128	132	132	137	127	..	138	..	133	142
23. *Æsculus Hippocastaneum*	120	..	..	122	110	98	121	122	121	..	124	127	123	128	132	129	137	123	124	138	..	126	141
24. *Galium Aparine*	127	140	..	..	156	155	128	142	115	..	..	..	136	134	146	130	..	141	..	..	..	..	..
25. *Cratægus Oxyacantha*	122	..	124	126	115	112	129	133	122	..	131	131	126	129	133	124	142	126	134	138	..	145	140
26. *Cytisus Laburnum*	122	..	..	127	111	125	125	134	124	..	130	128	125	135	136	132	139	134	137	134	..	140	..
27. *Potentilla anserina*	139	140	125	..	134	125	135	134	124	..	..	..	136	148	139	152	144	153	142	142	..	169	148
28. *Lotus corniculatus*	142	..	130	..	112	108	135	129	124	..	..	139	147	149	135	151	145	144	143	144	..	142	..
29. *Hieracium Pilosella*	142	140	137	..	..	132	..	146	127	..	..	..	..	147	168	141	155	144	134	..	..	148	..

TABLE I.—DATE (DAY OF YEAR) OF FIRST FLOWERING OF PLANTS, 1890.—*Continued.*

Name of Plant.	A. England, SW.				B. Ireland, S.		C. England, S.					D. England, Midlands.							E. Englnd, E.	F. England, NW.		H. Scotlnd, W.	I. Englnd, NE.
	Babbacombe.	Tiverton.	Westward Ho.	Wells.	Killarney.	Wicklow.	Pennington.	Buckhorn Weston.	Salisbury.	Swanley.	Ealing.	St. Albans.	Oxford.	Northampton.	Thurcaston.	Belton.	Macclesfield.	Hodsock.	Tacolneston.	Settle.	Claughton.	Tynron.	Durham.
30. TRIFOLIUM REPENS	143	..	149	..	147	114	143	146	142	..	..	..	..	148	142	152	162	135	138	172	..	169	..
31. *Chrysanthemum Leucanthemum*	142	151	149	135	146	128	137	135	128	..	125	139	140	149	151	149	155	144	145	169	..	161	165
32. *Lychnis Flos-cuculi*	143	147	141	..	149	..	144	142	145	..	..	..	136	149	152	..	..	154	145	..	..	167	180
33. *Lathyrus pratensis*	158	..	155	..	..	146	157	152	143	..	..	..	174	170	158	..	162	164	149	..	..	165	..
34. *Iris Pseud-acorus*	152	..	137	..	131	148	141	..	149	..	..	..	149	169	..	153	161	158	..	..	..	..	..
35. *Rosa canina*	158	..	137	150	151	152	153	150	144	..	152	152	..	161	157	159	171	157	152	167	..	166	177
36. ACHILLEA MILLEFOLIUM	178	..	168	..	172	172	172	149	167	..	..	173	185	173	166	181	173	175	182	182	..	180	..
37. MALVA SYLVESTRIS	163	..	155	..	..	151	150	164	160	..	..	..	170	173	169	..	169	164	..	185	195	..	..
38. *Stachys sylvatica*	..	..	155	..	..	159	157	157	158	..	181	166	160	161	163	..	164	170	..	184	..	185	..
39. *Spiræa Ulmaria*	170	..	..	..	172	168	182	..	173	..	..	..	175	173	177	173	173	176	..	181	..	178	180
40. *Prunella vulgaris*	163	..	175	..	152	148	152	154	172	..	..	..	160	170	166	..	170	168	..	183	..	185	..
41. *Ligustrum vulgare*	165	..	179	163	..	157	161	..	163	..	..	..	174	161	170	170	179	159	..	198	..	..	..
42. *Vicia Cracca*	167	..	177	..	176	162	167	155	171	..	..	..	175	170	168	..	173	184	180	191	..	184	..
43. *Senecio Jacobæa*	191	..	167	191	..	173	188	211	189	..	..	..	..	171	196	..	188	183	185	183	..	194	..
44. CENTAUREA NIGRA	172	..	182	..	..	182	168	171	184	..	..	173	..	170	175	..	186	174	..	183	195	198	..
45. *Galium verum*	179	..	180	..	..	175	195	169	176	..	..	..	..	170	175	181	187	180	185	195	..	180	..
46. *Carduus arvensis*	178	..	179	..	..	..	182	..	182	..	..	..	..	186	183	..	188	182	..	210	..	197	..
47. CAMPANULA ROTUNDIFOLIA	..	..	..	..	..	..	174	..	200	..	..	188	..	..	168	..	186	197	..	188	195	188	..
48. *Galeopsis Tetrahit*	..	..	..	..	..	..	..	..	208	..	..	..	..	..	186	..	192	..	..	..	..	188	..
49. CONVOLVULUS SEPIUM	202	..	..	174	..	191	..	187	208	..	..	..	..	..	..	187	192	174	192	191	..	..	..
50. *Hedera Helix*	266	..	..	254	254	266	272	..	..	..	269	..	..	263	..	..	281	260	..	..	..	..	..

English Names of above Plants.—1. Hazel. 2. Lesser Celandine. 3. Dog's Mercury. 4. Coltsfoot. 5. Daffodil. 6. Marsh Marigold. 7. Great Sallow. 8. Wood Anemone. 9. Ground Ivy. 10. Black-thorn. 11. Cowslip. 12. Cuckoo Flower. 13. Greater Stitchwort. 14. Blue-bell. 15. Upright Crowfoot. 16. Germander Speedwell. 17. Ribwort Plantain. 18. Garlic Hedge Mustard. 19. Bush Vetch. 20. Bugle. 21. Herb Robert. 22. Lilac. 23. Horse Chestnut. 24. Cleavers. 25. Hawthorn. 26. Laburnum. 27. Silver-weed. 28. Bird's Foot Trefoil. 29. Mouse-ear Hawkweed. 30. Dutch Clover. 31. White Ox-eye Daisy. 32. Ragged Robin. 33. Meadow Vetching. 34. Yellow Iris. 35. Dog Rose. 36. Milfoil. 37. Common Mallow. 38. Hedge Woundwort. 39. Meadow-sweet. 40. Self-heal. 41. Privet. 42. Tufted Vetch. 43. Ragwort. 44. Black Knap-weed. 45. Yellow Bedstraw. 46. Field Thistle. 47. Harebell. 48. Hempnettle. 49. Greater Bind-weed. 50. Ivy.

During January vegetation was everywhere remarkably forward. Throughout the next two months Wild Flowers were as a rule only moderately early, but from this time until the middle of June they were very early in making their appearance. During the rest of the Summer, and especially in July, their blossoming was greatly retarded.

TABLE II.—Date (Day of Year) of First Song and Migration of Birds, 1890.

District.	Stations.	Song.							Migration.						
		Song Thrush.	Nightingale.	Willow Wren.	Chiff-chaff.	Skylark.	Cuckoo.	Turtle Dove.	Flycatcher.	Swallow.	House Martin.	Sand Martin.	Swift.	Goatsucker.	Corncrake.
A.	Babbacombe	..	..	..	..	..	112	95	..	104	..	..	..	..	..
,,	Westward Ho	..	..	..	93	..	120	..	..	93	..	..	127	..	..
B.	Killarney	..	..	..	..	..	126	..	..	97	..	..	..	..	124
,,	Wicklow	..	..	..	88	54	89	..	..	103	..	141	127	..	115
C.	Pennington	7	110	..	90	32	106	..	143	104	..	..	127	129	126
,,	Buckhorn Weston ..	11	..	..	..	48	106	..	..	104	..	..	121	..	..
,,	Salisbury	..	..	..	..	70	106	..	..	106	116	108	115	..	136
,,	Ealing	12	109	..	..	12	110	..	..	99	..	..	131	..	..
D.	St. Albans.........	..	110	..	..	19	..	..	..	..	..	..	..	..	..
,,	Oxford	..	..	..	89	..	112	..	..	107	108	108	126	..	120
,,	Northampton	..	..	..	..	..	..	..	..	109	..	..	..	..	..
,,	Thurcaston	..	..	..	..	..	114	..	..	124	..	..	..	..	..
,,	Belton	..	109	..	..	39	112	99	140	110	126	128	138	..	134
,,	Macclesfield	36	..	88	..	43	116	..	..	130	130	133	142	..	130
,,	Hodsock..........	15	114	..	111	34	111	123	145	104	132	126	129	..	118
E.	Tacolneston	15	..	..	..	15	112	..	..	106	..	..	..	..	..
F.	Claughton	29	..	..	..	74	117	..	..	124	124	115	..	..	..
H.	Tynron	..	..	..	..	..	117	..	..	120	130	..	..	..	128
I.	Durham............	45	..	115	..	34	121	..	..	117	..	115	132	..	125

TABLE III.—Date (Day of Year) of First Appearance of Insects and Frog Spawn, 1890.

District.	Stations.	1. *Melolontha vulgaris.*	2. *Apis mellifica.*	3. *Vespa vulgaris.*	4. *Pieris Brassicæ.*	5. *Pieris Rapæ.*	6. *Anthocharis Cardamines.*	7. *Epinephile Janira.*	Frog Spawn.	Tadpoles.
A.	Babbacombe	..	88	65	..	90	143	..	..	..
,,	Westward Ho	138	..	119	..	..	116	165	..	..
B.	Killarney	..	..	..	101	..	..	..	49	..
,,	Wicklow	..	52	114	120	94	..	136	65	..
C.	Pennington	131	..	103	105	93	127	176	32	118
,,	Buckhorn Weston	133	10	125	..	107	125	..	..	..
,,	Salisbury	..	34	84	..	85	..	..	41	89
,,	Swanley	..	58	..	..	..	..	..	80	..
,,	Ealing	..	33	..	134	102	..	..	72	..
D.	St. Albans	..	67	..	95	98	..	..	71	..
,,	Oxford	..	45	..	..	89	117	..	77	99
,,	Northampton	..	71	..	..	106	..	..	69	..
,,	Thurcaston	..	..	..	..	119	138	175	..	..
,,	Belton	140	12	..	122	116	139	..	..	..
,,	Macclesfield	..	94	87	141	124	152	..	81	..
,,	Hodsock	142	31	113	120	..	138	..	67	94
E.	Tacolneston	..	55	..	95	..	137	..	..	..
F.	Claughton	..	120	..	..	129	..	..	..	..
I.	Durham	..	85	..	142	126	144	..	..	..

English Names of above Insects.—1. Cock Chafer. 2. Honey Bee. 3. Wasp. 4. Large Cabbage Butterfly. 5. Small Cabbage Butterfly. 6. Orange-tip Butterfly. 7. Meadow-brown Butterfly.

TABLE IV.—ESTIMATED YIELD OF FARM CROPS IN 1890.

Description of Crop.	England.					
	A. SW.	C. S.	D. Mid.	E. E.	F. NW.	I. NE.
Wheat	U. Av.	U. Av.	Av.	Av.	Av.	Av.
Barley	Av.	O. Av.	O. Av.	O. Av.	O. Av.	O. Av.
Oats	O. Av.	O. Av.	O. Av.	O. Av.	O. Av.	O. Av.
Corn Harvest began, average Date	225 (Aug. 13)	220 (Aug. 8)	223 (Aug. 11)	222 (Aug. 10)	231 (Aug. 19)	233 (Aug. 21)
Beans	O. Av.	O. Av.	O. Av.	O. Av.	O. Av.	O. Av.
Peas	O. Av.	O. Av.	O. Av.	O. Av.	O. Av.	Av.
Potatoes	U. Av.	Av.	O. Av.	U. Av.	O. Av.	O. Av.
Turnips	O. Av.	O. Av.	O. Av.	Av.	O. Av.	O. Av.
Mangolds	O. Av.	Av.	O. Av.	Av.	O. Av.	O. Av.
Hay	U. Av.	U. Av.	U. Av.	U. Av.	Av.	O. Av.

Description of Crop.	Scotland.			Ireland.	British Isles.
	H. W.	J. E.	K. N.	B. and G. S & N.	
Wheat	U. Av.	Av.	..	Av.	Av.
Barley	Av.	O. Av.	..	O. Av.	O. Av.
Oats	O. Av.	O. Av.	U. Av.	O. Av.	O. Av.
Corn Harvest began, average Date	247 (Sep. 4.)	251 (Sep. 8)	261 (Sep. 18)	240 (Aug. 28)	235 (Aug. 23)
Beans	Av.	O. Av.	..	..	O. Av.
Peas	..	..	..	..	O. Av.
Potatoes	U. Av.	U. Av.	Av.	U. Av.	U. Av.
Turnips	U. Av.	O. Av.	Av.	O. Av.	O. Av.
Mangolds	..	..	..	Av.	O. Av.
Hay	O. Av.	U. Av.	O. Av.	O. Av.	U. Av.

Symbols:—O. = Over. U. = Under. Av. = Average.

This Table has been compiled from Returns sent in to the *Agricultural Gazette* at the end of the Summer.

1890," these frosts were most severe on the South-eastern, Eastern and South Midland Counties. On the other hand, in the North of England and at the coast stations only moderate frosts prevailed. The areas within which serious injuries were done to shrubs, &c., appear, however, to have been very limited. These frosts necessarily gave a check to vegetation generally, for they lasted sufficiently long for the ground to become chilled to some depth. After the first week the weather remained fairly genial, so that in all districts March comes out as a rather warm month. The rainfall was about average, and there was comparatively little sunshine. The cold, dry and sunny weather of April proved very helpful to all farm and garden operations. Unfortunately, however, the frequent night frosts and cold winds proved very destructive to the blossoms of such hardy fruits as apples, pears and plums. May was another grand month for bringing all trees and plants gradually forward, and without serious check. Indeed, taking the Spring as a whole, it was an exceptionally favourable season.

TABLE V.—Estimated Yield of Fruit Crops in 1890.

Description of Crop.	England.					
	A. SW.	C. S.	D. Mid.	E. E.	F. NW.	I. NE.
Apples	U. Av.	U. Av.	U. Av.	U. Av.	U. Av.	U. Av.
Pears	U. Av.	U. Av.	U. Av.	U. Av.	U. Av.	U. Av.
Plums	Much U. Av.	Much U. Av.	Much U. Av.	Much U. Av.	Much U. Av.	Much U. Av.
Raspberries	O. Av.	O. Av.	O. Av.	O. Av.	O. Av.	Av.
Currants	O. Av.	O. Av.	O. Av.	O. Av.	O. Av.	Av.
Gooseberries	O. Av.	O. Av.	O. Av.	O. Av.	O. Av.	Av.
Strawberries	O. Av.	O. Av.	O. Av.	O. Av.	O. Av.	O. Av.

Description of Crop.	Scotland.			Ireland.	British Isles.
	H. W.	J. E.	K. N.	B. and G. S & N.	
Apples		U. Av.		U. Av.	U. Av.
Pears		U. Av.		U. Av.	U. Av.
Plums		U. Av.		U. Av.	Much U. Av.
Raspberries		O. Av.		O. Av.	O. Av.
Currants		O. Av.		O. Av.	O. Av.
Gooseberries		O. Av.		O. Av.	O. Av.
Strawberries		O. Av.		O. Av.	O. Av.

Symbols:—O. = Over. U. = Under. Av. = Average.

This Table has been compiled from Returns sent in to the *Gardeners' Chronicle* and the *Garden* during the Autumn.

Observers' Notes.

March.—*Babbacombe* (A.). Vegetation was much injured by the severe frosts in the beginning of the month. *Wicklow* (B.). Hawthorn and Horse chestnut were in many places out in leaf during the last week. *Pennington* (C). Fruit trees in blossom much earlier than usual. Wild fowl very scarce all the season. *Buckhorn Weston* (C.). Although the first flowering is no earlier than usual, I think the general flowering is. *Salisbury* (C.). 26th. Leaves of Horse chestnut open. *Ealing* (C.). Vegetation, which had been at a standstill during the first half of the month, advanced very rapidly during the remaining fortnight. *Hodsock* (D.). Vegetation nearly a month earlier than usual. 10th. Apricot in blossom. 16th. Peach in blossom.

April.—*Babbacombe* (A.). Vegetation forward at the end of month. 5th. Hazel and sycamore in leaf. 26th. Common poplar and Field elm in leaf. *Killarney* (B.). But few swallows seen up to end of month. *Pennington* (C.). At end of month everything looked unusually forward and green for the time of year. 3rd. Chestnut in leaf. 11th. Wryneck heard. *Buckhorn Weston* (C.). Foliage forward. *Salisbury* (C.). Fruit of elms very plentiful this year. 19th. Ash in flower. *Thurcaston* (D.). Very cold nights. *Hodsock* (D.). A few leaves out on beeches at end of month. *Tynron* (H.). There is an extraordinary promise of blossom, especially on the hawthorn.

May.—*Babbacombe* (A.). Vegetation was forward and the bloom on the flowering shrubs and trees luxuriant. Leafing as follows: 2nd, Beech and Wych Elm; 7th, Lime; 12th, Ash; and 14th, Oak. *Westward Ho* (A.). 15th. Oaks well out in leaf. *Wells* (A.). Vegetation progressed rapidly early in this month. *Pennington* (C.). Dates of first flowering still in advance of ordinary years. 17th. Cut first rose on wall. *Buckhorn Weston* (C.). Dog Rose in flower earlier than

in any year since 1882. *Hodsock* (D.). 14th. Horse chestnut in full bloom. *Tynron* (H.) 31st. Potatoes injured by frost, also ferns by wayside and in fields, no such severe frost so late in the spring for many years.

The Summer of 1890.

During June the weather was somewhat cold and sunless, but on the other hand there were many refreshing showers and but few cold nights, so that all crops made steady and uninterrupted progress. Towards the end of the month, however, there came heavy rains which greatly interfered with the hay harvest. July and August, the two months on which so much depends, as they are generally the warmest of the twelve, proved this year unseasonably cold and very wet. A great deal of the hay crop was consequently badly damaged, while much corn was beaten down and otherwise injured by the persistent and often heavy rainfall. In many parts of the country the potato disease made its appearance unusually early, and at the end of the summer threatened to become general. Flowers were at no time abundant, but many varieties remained in blossom a much longer time than usual. The cool showery weather favoured the growth of trees, shrubs, grass and roots, as well as that of most vegetables.

Observers' Notes.

June.—*Babbacombe* (A.). Haymaking began on the 16th; much hay was stacked by the 24th, but the heavy showers which afterwards prevailed interfered with the remaining harvest work. *Wells* (A.). 1st. First grass cut. *Pennington* (C.). 1st. Grass first cut. Very little hay carried at end of month. *Thurcaston* (D.). A cold month. Temperatures below 32° five times indicated by grass minimum. Roses much infested with aphides and larvæ. *Tynron* (H.). May brought forward, but June has delayed, blossom. *Durham* (I.). 28th. Gorse most beautifully in blossom.

July.—*Babbacombe* (A.). Haymaking interfered with by wet weather. Corn crops much laid and injured by frequent rains. *Westward Ho* (A.). Very cold and wet up to 18th. *Pennington* (C.). Haymaking furnished a fair crop, but it was indifferently harvested owing to constant rain. *Buckhorn Weston* (C.). The hay crop heavy but not harvested in good condition. *Thurcaston* (D.). Strawberries plentiful, and lasted longer than usual. *Claughton* (F.). Honeysuckle and wild roses very abundant this summer.

August.—*Babbacombe* (A.). 9th. Hay harvest finished. Corn harvest much interfered with by continuously showery weather. *Pennington* (C.). Harvest operations much hindered by unsettled weather, and at end of month much still to be gathered in, especially barley. Pastures and lawns green throughout the summer. Bees swarmed and worked well early in the season, but suffered from the unsettled weather as well as from the inroad of wasps. Wasps numerous, butterflies scarce.

The Year ending August 1890.

The weather of the autumn, winter and spring, and of the first summer month (June) could scarcely have been more favourable for vegetation, but in general that of July and August proved altogether as unpropitious.

DISCUSSION.

Mr. BLANFORD inquired whether any steps had been taken to ascertain an average date of flowering, &c., of the various plants for the purpose of comparison.

Mr. WILSON said, respecting the question of average date of flowering, that one element of error might be eliminated by observers cultivating the wild flowers to be observed in their own garden. It was curious how one individual plant or tree was invariably ahead of all others of a similar kind. There was a Horse chestnut tree in Harpenden Village which was always a week or two earlier in leafing and flowering than others in the district, and so far as he knew its position was not more favourable than that of other trees. As regarded the crops, wheat grown at Rothamsted in 1890, on a field dressed with farm-yard manure, gave an exceptionally good crop, the highest of the forty years during which records had been kept. Apples and pears were scarce; plums very scarce; strawberries very abundant; gooseberries and currants about average; peaches good. He thought the plan followed at Montpellier, of having the test plants near the thermometer screen and regularly inspected, was the only safe one.

Mr. TRIPP thought it would be interesting if averages could be obtained. There was a valuable table of averages given in the *Cobham Journals*, kept by Miss Molesworth, but of course that would not be suitable for comparison with all places, as the average dates would vary in different districts. It would be interesting, too, to find out with regard to the potato crop, how far certain districts and certain different classes of potatoes were affected.

Mr. SYMONS gave a short history of the phenological observations, and stated that the matter had been brought under the notice of the Scientific Societies' Committee of the British Association at their meeting in the past autumn, when a long discussion had ensued which he hoped would result in the co-operation of the various local scientific societies scattered throughout the country. Phenological observations were much farther advanced on the Continent than in England. The question of the *cultivation* of plants had been argued over and over again, but there was this to be said about it, that a cultivated plant is taken away from its natural conditions, and placed amid artificial surroundings. At Montpellier there was a little garden of cultivated plants in close proximity to the thermometer screen, and it was the duty of the observer to note the daily progress of these plants. He was not prepared to say whether the plan was worthy of imitation or not.

Mr. MAWLEY, in reply, said that averages were very necessary for the purpose of comparison. He had not introduced them into the tables this year as he had intended, as it was the last time the same list of plants, birds and insects would be used. Next year a new and simpler system of observation would be adopted, and he would endeavour to obtain, as far as possible, approximate averages for all the plants, &c., on the new list. The observation of cultivated trees and plants would not be likely to afford comparable results, as the varieties of most of them were now so numerous, and the methods of cultivation so different.

THE CLIMATE OF HONG-KONG.

By WILLIAM DOBERCK, Ph.D., F.R.Met.Soc.

(Abstract.)

[Received July 30th.—Read December 17th, 1890.]

The latitude of Hong-Kong being 22° 18′ N, the Colony is situated within the tropics, but the winter is cool, its mean temperature being about 60°, whereas the mean temperature of the summer months rises a little above 80°. There is a large and well-marked annual variation of climate, but it is very hot in the sun all the year round. Palm trees, pomelos and oranges thrive here. Rice, sugar-canes and pine-apples are among the most extensively cultivated crops. Chinese fir trees and bamboos grow wild, and the latter attain to great size if allowed to grow. Banian trees are also common. Vines do not come to perfection as the winter temperature is not low enough to harden the wood.

In summer the dampness of the air is excessive; and Europeans suffer much from prickly heat, produced in consequence of the heat and dampness. The natives are also much subject to diseases of the skin, especially the different varieties of Tinea. Malarial fevers and diarrhœa are the worst hot weather diseases, the former chiefly of an intermittent type in summer. They are worst in August and September, when the Colony is under the influence of the high-pressure areas preceding and lying to the north of typhoons. In these areas the wind is light and the air descending, so that it is stifling, dusty, and probably full of bacteria. Want of sleep lays the foundation for diseases of the brain.

In autumn the dampness of the air decreases, and the temperature falls often rather suddenly when the North-east monsoon sets in. This causes affections of the chest and catarrhs, but there is very little consumption. Europeans enjoy almost an immunity from phthisis. Malarial fevers are now more of the remittent type. Small-pox is usually endemic, but occasionally it assumes an epidemic form, beginning in November and lasting till spring.

In winter dysentery—the dreaded scourge of the Pacific—occurs. This is the worst disease of the Chinese coast, as it tends to become chronic, or leads to abscess of the liver, which quickly terminates fatally. Cholera is not much feared out here, and does not often occur. In spring, simple continued fevers and rheumatism are common diseases.

The most unhealthy places in the Colony are situated in ravines between the hills, near marshy land or paddy fields. In those places the ague is deadly. Between one or two thousand feet up on the hills the air is much purer, and fever less common and of a milder type, which is, as a rule, easily cured by a few doses of quinine. To live at such a height is agreeable, as the air is cooler and fresher, although much damper than below, and frequently saturated with moisture in the summer.

At the Hong-Kong Observatory the cistern of the barometer is placed 109 feet, the bulbs of the thermometers 108 feet, the anemometer 149 feet, and the rain-gauge 105 feet, above mean sea-level. The bulbs of the thermometers are 4 feet, the rim of the rain-gauge 21 inches, and the cups of the anemometer 45 feet, above the ground.

At Victoria Peak the barometer is 1819 feet above mean sea-level. The bulbs of the thermometers are 4 feet, and the rim of the rain-gauge 1 foot, above the ground.

Tables I. and II. give the mean results of the principal elements at the Hong-Kong Observatory and at the Victoria Peak for the 5 years 1884-1888.

TABLE I.—HONG-KONG OBSERVATORY.—METEOROLOGICAL RESULTS, 1884-88.

(Barometer 109 ft. above mean sea level).

Months.	Barometer Reading reduced to 32° Fah.	Temperature.					Humidity.	
		Means.			Extremes.		Relative.	Tension of Vapour.
		Mean.	Max.	Min.	Max.	Min.		
	Ins.	°	°	°	°	°	o/o	In.
January ..	30·053	59·7	63·1	56·1	74·4	41·8	74	·391
February	30·042	55·3	58·2	52·1	70·0	40 6	78	·350
March ..	29·947	62·0	66·1	59·0	78·4	48·8	85	·481
April	·844	69·6	74·4	67·1	84·8	56·5	86	·635
May . ..	·765	75·9	80·4	73·5	88·4	65·8	84	·765
June	·648	80·2	84·4	77·5	89·3	69·2	83	·861
July	·611	81·5	85·5	78·1	92·9	73·8	83	·890
August ..	·637	80·9	85·0	77·3	90·4	72·2	83	·874
September	·722	80·3	84·3	77·0	90·7	70·8	76	·793
October..	29·903	76·0	79·1	72·7	86·1	60·8	70	·639
November	30·012	68·9	73·4	65·7	82·6	55·0	64	·462
December	30·063	62·4	66·8	59·3	76·3	44·8	64	·370
Year	29·854	71·1	75·1	67·9	92·9	40·6	78	·626

Months.	Rainfall.			Mean hourly velocity of the wind.	Amount of Cloud.	Sunshine.	
	Average	Greatest fall in one day.	Mean No. of hours during portion of which rain fell.			Average.	Percentage of possible duration.[1]
	Ins.	Ins.		Miles		Hours	
January	2·30	3·920	43	15·5	6·7	131·2	42
February	2·70	1·265	73	16·3	8·1	63·2	21
March	4·85	3·580	67	16·7	8·3	82·4	26
April	7·68	5·210	80	15·1	8·0	115·3	35
May	7·45	5·975	73	13·5	7·8	138·1	39
June	16·47	12·630	120	13·5	7·7	155·1	42
July	15·50	13·480	128	11·8	6·9	194·2	51
August	14·85	6·555	96	9 5	6·5	200 0	54
September	7·72	5·855	68	12·1	5·6	212·2	60
October	2·99	2·240	28	14·4	4·3	231·3	69
November	0·77	0·925	20	13·5	4·4	214·9	73
December	1·60	1·670	29	13·0	4·0	208·7	65
Year	84·88	13·480	825	13·7	6·5	1946·6	48

[1] Fours years only 1885-8.

TABLE II.—VICTORIA PEAK.—METEOROLOGICAL RESULTS, 1884–88.

(Barometer 1819 ft. above mean sea-level.)

Months.	Barometer Reading reduced to 32° F.	Temperature.					Humidity.		Rainfall.		Mean Hourly Velocity of the Wind.
		Means.			Extremes.		Relative.	Tension of Vapour.	Average.	Greatest Fall in one day.	
		Mean.	Max.	Min.	Max.	Min.					
	Ins.	°	°	°	°	°	o/o	In.	Ins.	Ins.	Miles.
January	28·262	54·1	57·9	50·5	69·1	36·0	86	·371	3·88	5·01	25
February	·232	49·9	53·5	46·3	67·8	35·3	90	·333	3·57	1·75	25
March ..	·187	58·4	62·4	54·4	72·3	42·0	90	·461	4·84	5·10	24
April	·105	65·3	68·7	61·9	76·5	47·8	93	·594	8·72	8·40	25
May	28·055	70·2	73·1	67·6	78·3	57·2	94	·705	8·38	4·85	24
June	27·960	73·6	76·0	71·3	81·3	64·8	95	·794	19·34	14·50	26
July	·928	75·3	77·9	73·2	84·2	69·8	93	·822	18·00	14·56	24
August ..	27·953	75·0	77·7	72·7	82·9	67·0	93	·811	17·70	9·20	23
September	28·025	74·3	77·5	71·6	82·5	66·0	88	·750	6·51	6·50	23
October ..	·178	69·8	73·4	66·6	79·7	58·3	84	·622	2·75	1·71	24
November	·254	62·6	66·7	58·9	74·9	44·0	77	·458	1·16	1·20	23
December	28·277	56·2	60·6	51·8	69·0	40·1	77	·360	1·99	2·36	24
Year ..	28·118	65·4	68·8	62·2	84·2	35·3	88	·590	96·84	14·56	24

The highest temperature of the air occurs about 2 p.m., and the lowest between 6 a.m. and 7 a.m. in winter, and about 5 a.m. in summer.

The relative humidity values vary inversely as the temperature, while the actual amount of vapour is greatest a few hours after sunset and least shortly after sunrise. In winter there is nearly as much vapour at the Peak as at the Observatory, but in summer there is less.

The amount of bright sunshine is greatest in November and smallest in February. The daily maximum occurs about noon, and there is more sunshine in the afternoon than in the forenoon.

The hourly intensity of rainfall is greatest about noon and least about midnight, while the rainfall itself is a maximum shortly after sunrise and a minimum about sunset. Most rain falls in June and least in November. There falls on an average ¼ more rain on top of the Peak than at the Observatory, but in September and October, when the rain is chiefly collected during typhoons, there appears to fall less on the top of the Peak.

Rain falls more frequently at sunrise than at sunset, particularly in summer.

The mean wind velocity is greatest in spring when the Trade wind and the Easterly monsoon co-operate, and least in August when the Southerly monsoon is blowing. At the Peak the wind blows nearly as strong during summer as during winter. The wind is strong about 1 p.m. and least shortly after sunset. This causes, during the hottest months of the year, a secondary maximum of temperature shortly after sunset which is particularly well marked during cloudy weather. In winter, at times when the North-east Trade winds blows strongly, its force is often greatest at night, or during the early morning hours.

Fogs are common in March, and occur also during typhoons in August and September. Electric phenomena prevail in August. Unusual visibility of distant objects prevails when the air is frequently cleared from dust by heavy rain in July. Dew is common in August, when also halos and coronæ are most frequent. Rainbows are comparatively rare in hot countries, where the rain is so heavy and the sun usually too high in the sky. Hail is unknown here.

Cumulus is the common cloud in China. Cirrus is most frequent during typhoons, and cumulo-stratus during the hottest part of the year.

The amount of cloud is greatest in March and least in December. On an average there are more clouds at sunrise than about midnight. But looking at the different seasons, it is seen that in summer the amount is greatest in the afternoon and least about midnight, while in winter the amount is greatest during the early morning hours and least in the afternoon.

The daily maximum of rain was exceeded in 1889, when there fell 22·535 inches of rain between 3.30 p.m. on the 29th May, and the same time on the 30th.

At the Peak, the minimum thermometer exposed one inch above the grass registered below freezing point. That never occurs at sea-level in Hong-Kong, but a little farther inland, as at Canton, frost is not unknown.

The barometric tide is large in winter (when the air is dry) and small in summer (when it is damp). The mean diurnal variability of temperature—the mean of the differences of temperature of each day and the next—is greatest in winter. The number of days on which at least 0·01 inch of rain fell at the Observatory was a minimum in November and a maximum in June and July. The hourly intensity of rain is greatest in July and least in February. The directions whence clouds in different levels come, together with the wind directions, prove the direction of the wind to veer on ascending in the atmosphere. The height of the lower clouds is least in April and greatest in November.

The rate at which the temperature falls on ascending the atmosphere is least in March, when the relative humidity is great, and the clouds are low, and it is greatest in June.

PROCEEDINGS AT THE MEETINGS OF THE SOCIETY.

NOVEMBER 19TH, 1890.

Ordinary Meeting.

BALDWIN LATHAM, M.Inst.C.E., President, in the Chair.

WILLIAM FREDERICK BLAY, Claremont House, Highgate, Walsall;
THOMAS HENRY NEWPORT DAVIS, Orleton, near Tenbury;
WILLIAM GREATHEED, 67 Chancery Lane, W.C.;
ERNEST WILLIAM GREG, Higher Dunscar, Bolton;
JOSEPH HORROCKS, 10 Union Street, Southport;
WILLIAM LAWFORD, M.Inst.C.E., Parliament Mansions, S.W.;
Major SOMERSET HENRY MAXWELL, Arley Cottage, Mount Nugent, Co. Cavan;
Sir JOHN SHELLEY, Bart., J.P., Shobrooke Park, Crediton; and
ROBERT STODART WYLD, Jun., M.Inst.C.E., F.G.S., Liverpool Corporation Waterworks, Oswestry,
were balloted for and duly elected Fellows of the Society.

The PRESIDENT delivered an Address on "THE RELATION OF GROUND WATER TO DISEASE." (p. 1.)

On the motion of Dr. WILLIAMS, seconded by Mr. H. J. MARTEN, the thanks of the Society were given to the President for his Address.

DECEMBER 17TH, 1890.

Ordinary Meeting.

HENRY F. BLANFORD, F.R.S., Vice-President, in the Chair.

TREVOR FOWLER, L.R.C.P., Epping;
ARTHUR GREG, Eagley, Bolton; and
HENRY WOOLCOCK, Assoc.M.Inst.C.E., Rickerby House, St. Bees,
were balloted for and duly elected Fellows of the Society.

Mr. J. S. HARDING and Mr. H. S. WALLIS were appointed Auditors of the Society's Accounts.

The following Papers were read:—

"NOTE ON A LIGHTNING STROKE PRESENTING SOME FEATURES OF INTEREST." By ROBERT H. SCOTT, M.A., F.R.S. (p. 18.)

"NOTE ON THE EFFECT OF LIGHTNING ON A DWELLING HOUSE AT TWICKENHAM, SEPTEMBER 23RD, 1890." By ARTHUR BREWIN, F.R.Met.Soc. (p. 19.)

"WIND SYSTEMS AND TRADE ROUTES BETWEEN THE CAPE OF GOOD HOPE AND AUSTRALIA." By Capt. M. W. C. HEPWORTH, F.R.Met.Soc. (p. 21.)

"REPORT ON THE PHENOLOGICAL OBSERVATIONS FOR 1890." By EDWARD MAWLEY, F.R.Met.Soc. (p. 27.)

"THE CLIMATE OF HONG-KONG." By W. DOBERCK, Ph.D., F.R.Met.Soc. (p. 37.)

CORRESPONDENCE AND NOTES.

Remarkably Low Temperature on November 28th, 1890.

Mr. S. Rostron, F.R.Met.Soc., of Beddington, Surrey, made the following interesting notes on the remarkably low temperature which occurred on the afternoon of November 28th, 1890:—

"Early a.m., overcast and snowing, small flakes. Wind East-south-east, gentle. Barometer 29·90 ins., rising. I was struck with low temperature (9.20 a.m. 22°·0), with overcast sky and snow. In town at 1.30 p.m. When I crossed St. James's Park the water was open and the thermometer opposite Marlborough House read 24°·0, but on returning at 3.40 the thermometer read 21°·0, and the water was frozen from end to end. I left Victoria at 4.5 p.m. At Balham the sky was clearing. At Carshalton the sky was cloudless with haze from excessive cold; snow musical, my beard froze at once, and my ears were very painful. Carshalton pond smoked like a cauldron. In Acres Lane I heard a wood fence cracking. I arrived home at 5.15, and found minimum temperature had been 2°·3, it was then 5°·0; the thermometer on the snow had been —8°·0, it was then —5°·0. Mist came up covering sky, and the temperature rose fast; at 6 o'clock it was 10°·0; 7 o'clock, 12°·3 and cloudy; 9 o'clock, 15°·2; and 11 o'clock, 15°·2.

"My gardener told me that he had seen the temperature 3°·0 in the Stevenson screen at 4.45 p.m.; at 4.30 it was 5°·0; at 3 o'clock, 18°·0; and 1 o'clock p.m. 22°·0. The sky cleared and the snow stopped about 2 o'clock, the temperature then fell very fast after 3 o'clock. The minimum must have been about 5 p.m., the extreme cold lasting only a few minutes."

Jamaica Meteorology.

Mr. Maxwell Hall has given in the *Supplement to the Jamaica Gazette*, Vol. XIII. No. 32, the results of the meteorological observations made at Kingston during the ten years ending May 1890. The mean results for the whole period are as follows:—

Month.	Barometric Pressure reduced to Sea-Level.	Temperature.				Wind, S.E. Miles per diem.	Vapour.		Amount of Cloud.	Rainfall.	
		Mean.	Mean Max.	Mean Min.	Mean Range.		Dew-Point.	Humidity.		Kingston.	The Island.
	Ins.	°	°	°	°		°	%		In.	In.
January	30·054	74·6	86·4	66·8	19·6	68	66·7	78	2·9	·96	3·87
February	·049	74·7	85·8	66·8	19·0	72	66·7	78	2·7	·32	2·62
March	·034	75·8	85·7	67·8	17·9	77	67·6	77	2·9	1·59	2·88
April	30·008	77·9	86·5	69·8	16·7	68	69·1	75	3·9	1·02	4·18
May	29·979	79·4	87·2	72·4	14·8	74	71·4	78	5·6	6·00	8·40
June	30·000	80·8	88·5	73·8	14·7	115	72·8	78	5·7	5·51	7·83
July	30·024	81·1	89·7	73·5	16·2	103	72·5	76	5·2	2·15	4·32
August	29·983	80·4	89·4	73·2	16·2	80	73·0	79	5·5	4·09	6·83
September	·956	80·1	89·7	73·3	16·4	70	73·1	80	6·2	3·59	6·86
October	·937	78·9	88·9	72·1	16·8	56	72·2	81	5·8	4·69	7·84
November	29·962	77·8	88·9	70·7	18·2	53	70·1	78	4·4	1·22	5·07
December	30·005	75·7	87·0	68·4	18·6	57	68·0	78	3·8	1·50	5·60
Year........	29·999	78·1	87·8	70·7	17·1	89	70·3	78	5·5	32·64	66·30

From June 1880 to December 1886 the readings were taken at intervals of eight hours, viz. at 7 a.m., 3 p.m. and 11 p.m. local mean time; the daily means were assumed to be the means of the three eight-hourly readings; but since

January 1887, the readings have been taken at 7 a.m. and 8 p.m. only; and the daily means were deduced by applying to the 7 a.m. and 8 p.m. readings their proper reductions; and from the daily means the monthly means have been deduced.

In the seventh column of the Table the wind is stated to be South-east, and this is in consequence of the regularity of the daily sea-breeze, which is almost invariably South-east at Kingston.

The highest temperature recorded during the ten years was 96°·1 on September 12th, 1880; and the lowest 56°·7, on December 4th, 1887.

RECENT PUBLICATIONS.

American Meteorological Journal. October-December 1890. Vol. VII. Nos. 6-8. 8vo.

Contains, among other information, the following articles:—Cyclical periodicity in meteorological phenomena; by E. D. Archibald (7 pp.).—Accessory phenomena of cyclones; by H. Faye (22 pp.).—State Tornado charts; by Lieut. J. P. Finley (4 pp.). The State dealt with herein is Nebraska.—Temperatures in and near forests; by M. W. Harrington (7 pp.).—Meteorological Congress at Limoges, France; by A. L. Rotch (5 pp.). This is an account of the proceedings at the meteorological section of the French Association for the Advancement of Science which was held at Limoges, August 7th to 14th, 1890.—Espy's Experiments on Storm generation; by Prof. W. Ferrel (8 pp.).—The Upper Yukon and the Mackenzie (14 pp.).—The thunderstorms and water spout at New Haven, Conn., on October 19, 1890; by H. J. Cox (4 pp.).—Temperature in anticyclones and cyclones; by Dr. J. Hann (8 pp.). This is a translation of Dr. Hann's paper in the *Meteorologische Zeitschrift*, June 1890.—Observations and studies on Mt. Washington; by Prof. H. A. Hazen (5 pp.).—Cyclones and tornadoes in North America; by J. Brucker (6 pp.).—The cooling of dry and moist air by expansion; by Prof. C. F. Marvin (6 pp.).

Bibliografía Meteorológica Mexicana que comprende las Publicaciones do Meteorologia, Fisica del Globo y Climatologia hechas hasta fines de 1889. Formada por Rafael Aguilar Santillán. 8vo. 1890. 48 pp.

This is a valuable catalogue of all the papers bearing on the meteorology of Mexico which have been published up to the end of 1889.

Das Wetter. Herausgegeben von Dr. R. Assmann. December 1890. 8vo.

This number contains a reprint of a very valuable article by Dr. Hann, "Warum es auf hohen Bergen kalt ist." Why is it cold on high mountains? This first appeared in the *Deutsche Revue*. From Dr. Hann's experience in dealing with Alpine observations, anything from his pen must command attention, and in the present article he deals with the results of solar radiation obtained by Violle and by Langley, and ends by pointing out why table lands are much warmer than isolated peaks of the same altitude, and how the essential characteristic of mountain peak climate is intense cold in summer and relative warmth in winter. He concludes by saying that if a peak of the height of the Himalayas existed among the Alps there would be no annual change of climate at the top, the winter there would be perpetual.

Memoirs and Proceedings of the Manchester Literary and Philosophical Society. Fourth Series. Vol. III. 8vo. 1890.

Contains two papers on meteorological subjects, viz. (1.) The Levanter clouds at Gibraltar; by J. J. Ashworth. This phenomenon is very similar to the Helm Wind of Cross Fell, in Cumberland.—(2.) Meteorology at the Sea-side: by Dr. W. G. Black.

Meteorologische Zeitschrift. Redigirt von Dr. J. Hann and Dr. W. Köppen. October-November 1890. 8vo.

The principal articles are:—Untersuchungen über die Temperatur und die Feuchtigheit der Luft unter, in und über den Baumkronen des Waldes, sowie im Freilande; von F. Eckert (7 pp.).—Beobachtungsergebnisse der neueren forstlich-meteorologischen Stationen im Deutschen Reiche; von F. Eckert (11 pp.). These two papers take up most of the October number. The first is a summary of a report by Dr. Lorenz Liburnau and the author on the results obtained from the Austrian forest stations. Some new forms of apparatus were used, the thermometers were Osnaghi's "turn over," the hygrometers were chemical, with aspiration. The chief contrast shown by the results to those of German stations is as regards the aqueous vapour at Ried, a station lying on the edge of the dry region of the Black Sea, where the wood shows an excess of moisture as compared with land outside. The second paper is a detailed comparison of the results from German stations *inter se*, and with Austrian stations.—Isogradienten-Karten für die ganze Erdoberfläche; von J. Kleiber (11 pp. and 2 plates). This is an attempt by a Russian Professor to give charts of the general gradients. The present paper deals only with January, and two maps are given, one of the North and South, the other of the East and West gradient. In each map two colours are used, one for North to South, the other from South to North, and so on. On the map for North and South gradients the boundaries between the two regions lie along parallels of latitude, in the other map they are less regularly arranged. Charts for July and for the year are promised.—Die Anwendung des Gesetzes der Flächen auf atmosphärische Strömungen; von Prof. Max Möller (7 pp.).—Ein Wunsch in Betreff der Ergebnisse der Anemometer-Aufzeichnungen: von Dr. J. M. Pernter (2 pp.). The author, who has been discussing the anemometrical data from the Säntis and other mountain stations, finds the reductions so laborious that he proposes that all observatories should publish tables giving the hourly velocity and frequency for the 16 points of the compass, and he gives a specimen table.

Philosophical Magazine. December 1890. 8vo.

Contains:—On the General System of Winds on the Earth; by Werner von Siemens (9 pp.). This is a translation of an article by the author from the *Sitzungsberichte der Koniglich preussischen Akademie der Wissenchaften zu Berlin*, Vol. XXX., 1890. The author says: The theory of the general system of winds may be summed up in the following statements:—

1. All motions of the air depend upon disturbances of the indifferent equilibrium of the atmosphere, and tend to bring about its restoration.

2. These disturbances are caused by the superheating of the strata of air lying nearest to the earth's surface through solar heat, by unsymmetrical cooling of the upper layers of the air through radiation, and by the piling up of masses of air in motion through obstructions occurring to the current.

3. The disturbances are balanced by means of ascending currents, which possess an acceleration of such a kind that the increase of velocity of the air is proportional to the diminution of its pressure.

4. Down-currents of equal magnitude correspond to the up-currents, and in these the velocity of the air is retarded in the same proportion as that of the upflow is accelerated.

5. If the heating of the lower strata of air takes place within a limited area, a local up-flow occurs reaching to the uppermost regions of the air, and presenting the appearance of whirling columns with ascending spiral currents of air inside, and similarly directed descending currents outside. The result of these whirling currents is a diffusion of the surplus heat of the lower strata through which the adiabatic equilibrium is disturbed, to the whole column of air which took part in the whirling motion.

6. When the sphere of disturbance of the indifferent (or adiabatic) equilibrium is very extended, compromising for instance the whole torrid zone, the equalisation of temperature can no longer be effected by local ascending whirling currents, but these must comprise the whole atmosphere. The conditions are the same as with local currents, viz. an accelerated ascent and retarded descent of the air, so that the velocity of the air due to the action of the heat is at the different latitudes approximately inversely proportional to the air-pressure prevailing there.

7. As the air of every latitude rotates with approximately the same absolute velocity in consequence of the constant meridional currents which the heat produces and maintains, and meridional combine with the terrestrial currents to form the great system of currents of air surrounding the whole earth, whose function it is to give a share of the surplus heat of the torrid zone to the whole atmosphere, by transferring equatorial heat and moisture to the middle and higher latitudes, and by originating local air-currents in them.

8. These latter are due to the local production of alternate increase and decrease of pressure through the disturbance of the indifferent equilibrium in the upper strata of the atmosphere.

9. The maximum and minimum air-pressures are effects of the temperature and velocity of currents of air in the higher strata of the atmosphere.

From what precedes, the investigation of the causes and effects of the disturbance of the indifferent equilibrium of the atmosphere may be considered as one of the most essential problems of meteorology, and the investigation of the geographical origin of the air-currents passing over us on their way to the poles as the most important problem in the prognostication of the weather.

Results of Rain, River, and Evaporation Observations made in New South Wales during 1889. H. C. Russell, B.A., C.M.G., F.R.S., Government Astronomer. 1890. 8vo. 183 pp. and 4 plates.

The record of the rainfall for 1889 shows that the year was a most favourable one. In the central parts of the Colony the rainfall for the three first months of the year was rather light, but in much of the Western, Southern, and Coast districts the rainfall was fairly abundant in these months, while for the remainder of the year the rainfall was abundant with scarcely any exception. All the tributaries of the Darling began to rise about the middle of April, and at the end of May a second and greater flood came on.

In May a phenomenal rainstorm came on, particularly in the metropolitan district, where it was heavier than any previous rainstorm since 1845. Over 20 inches fell in four days at the Observatory, and it is noteworthy that from 10 to 15 miles west of the Observatory it was much heavier, ranging from 23 to 27 inches in the same time. Fortunately the heaviest part of this storm was confined to the Metropolitan district, where, owing to the free course to tidal water, no serious floods occurred, but the rain was heavy enough over the Hawkesbury and Hunter rivers to produce high floods. The heaviest previous rainfalls at South Head, Sydney, were 20·12 ins. on April 29th, 1841, and 20·41 ins. on October 15th, 1844.

Symons's Monthly Meteorological Magazine. Vol. XXV. Nos. 297-299. October-December 1890. 8vo.

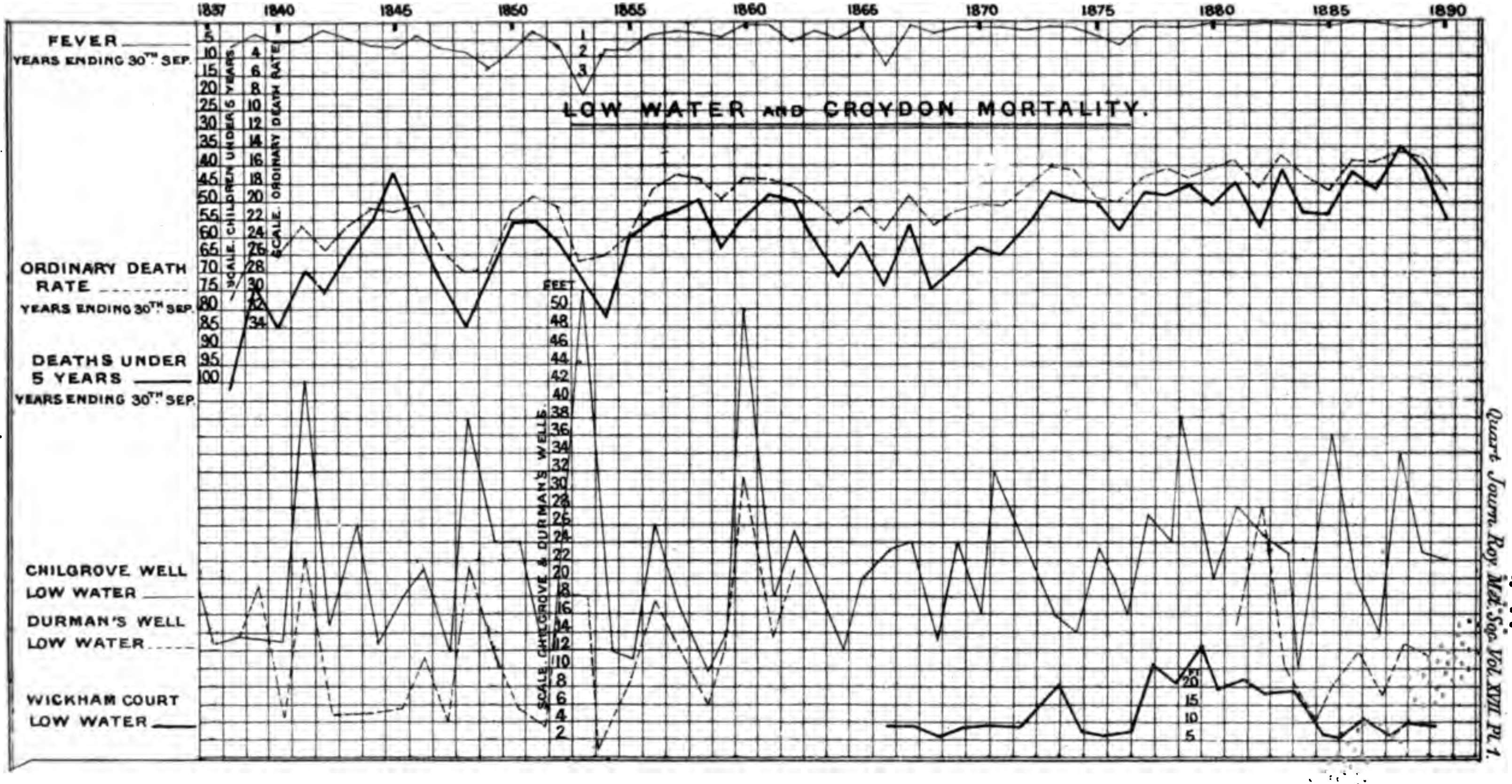
The principal articles are:—The Autumn Congresses (8 pp.). This gives an abstract of the meteorological papers read at the Meeting of the British Association at Leeds in September 1890.—Heavy hourly rainfall on Ben Nevis; by R. C. Mossman (1 p.).—Barometric Depressions; by Rev. G. T. Ryves, Prof. H. A. Hazen, Rev. J. Slatter, Rev. W. C. Ley, and W. H. Dines (4 pp.).—Hail Insurance (2 pp.).—Sharpest Frost in October for half-a-century (2 pp.).—Greenwich mean temperatures; by G. von U. Searle (1 p.).—Excessive frost in November (7 pp.). (See note by Mr. Rostron above on p. 42.)

TRANSACTIONS OF THE AMERICAN SOCIETY OF CIVIL ENGINEERS. Vol. XXIII. No. 448. 8vo. 1890.

This contains a paper by Mr. F. A. Velschow "On the cause of Trade Winds" (8 pp. and 2 plates).

TRANSACTIONS OF THE SANITARY INSTITUTE. Vol. X. 1888-9. 8vo. 1890. 876 pp.

This contains an account of the proceedings at the Congress held at Worcester in September 1889. In the Section of Chemistry, Meteorology and Geology, the President, Dr. J. W. Tripe, gave an exhaustive address on "Winds, with some remarks on their sanitary effects" (16 pp.).—Surgeon-Major W. G. Black also read a paper on "Meteorology at the Sea-side" (12 pp.)


LOW WATER AND CROYDON MORTALITY.
FEVER
YEARS ENDING 30TH SEP.
ORDINARY DEATH RATE
YEARS ENDING 30TH SEP.
DEATHS UNDER 5 YEARS
YEARS ENDING 30TH SEP.
CHILGROVE WELL LOW WATER
DURMAN'S WELL LOW WATER
WICKHAM COURT LOW WATER
SCALE. CHILDREN UNDER 5 YEARS.
SCALE. ORDINARY DEATH RATE.
SCALE. CHILGROVE & DURMAN'S WELLS.
FEET
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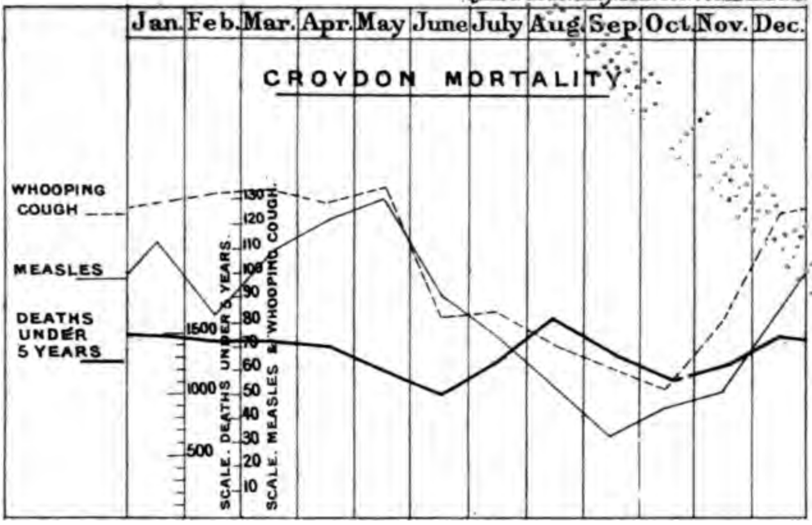
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CROYDON MORTALITY.
WHOOPING COUGH
MEASLES
DEATHS UNDER 5 YEARS
SCALE. DEATHS UNDER 5 YEARS.
SCALE. MEASLES & WHOOPING COUGH.
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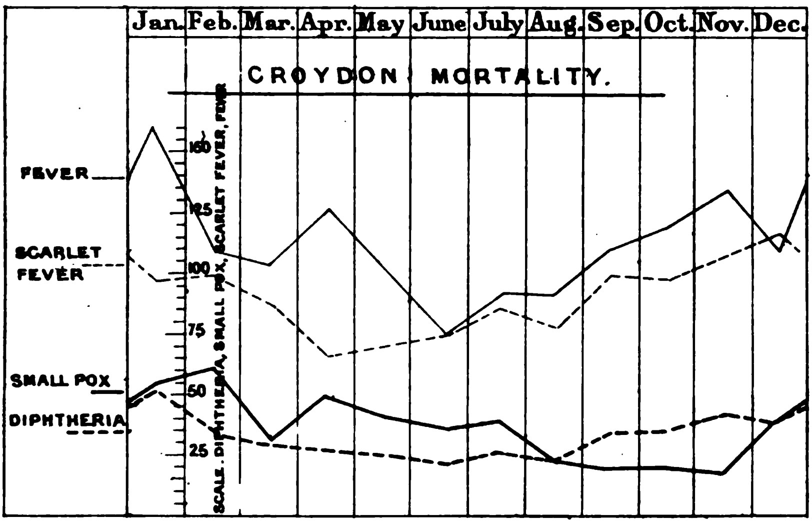
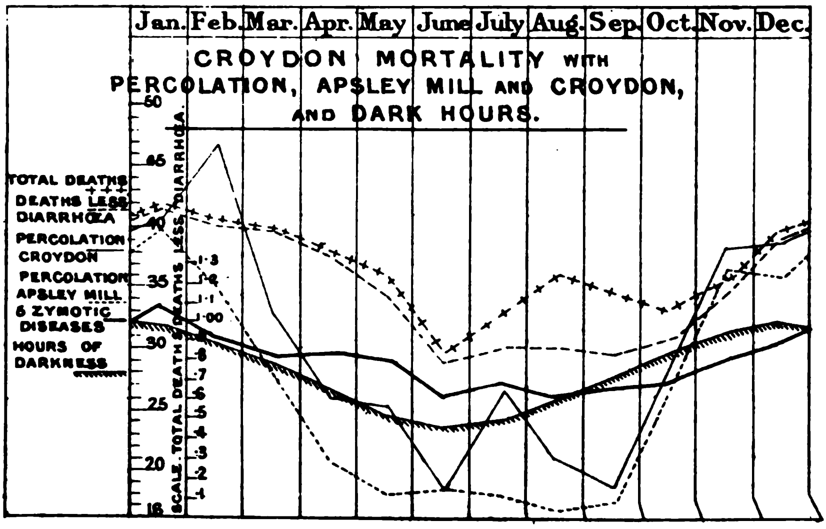
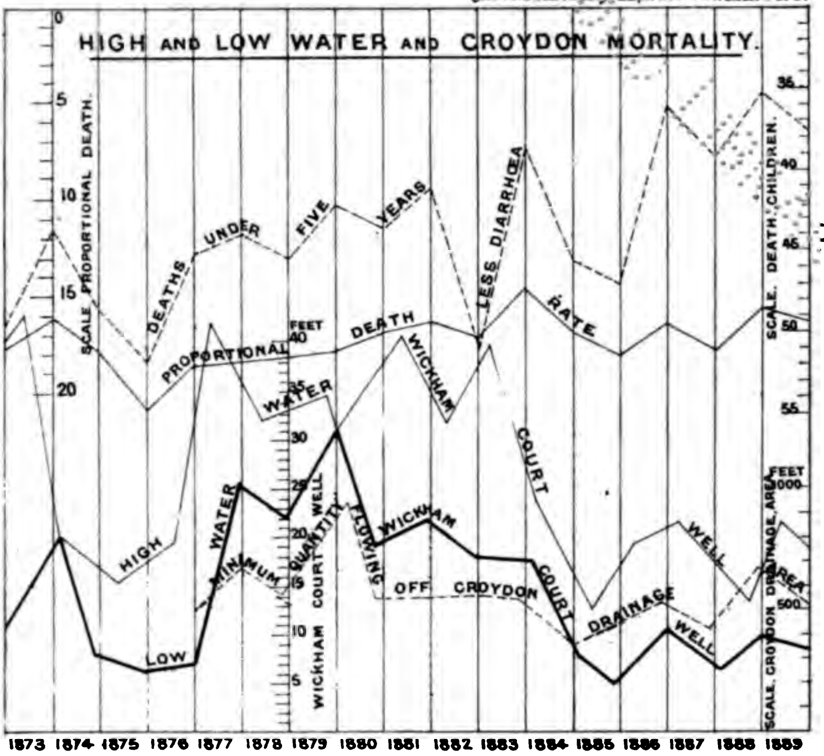
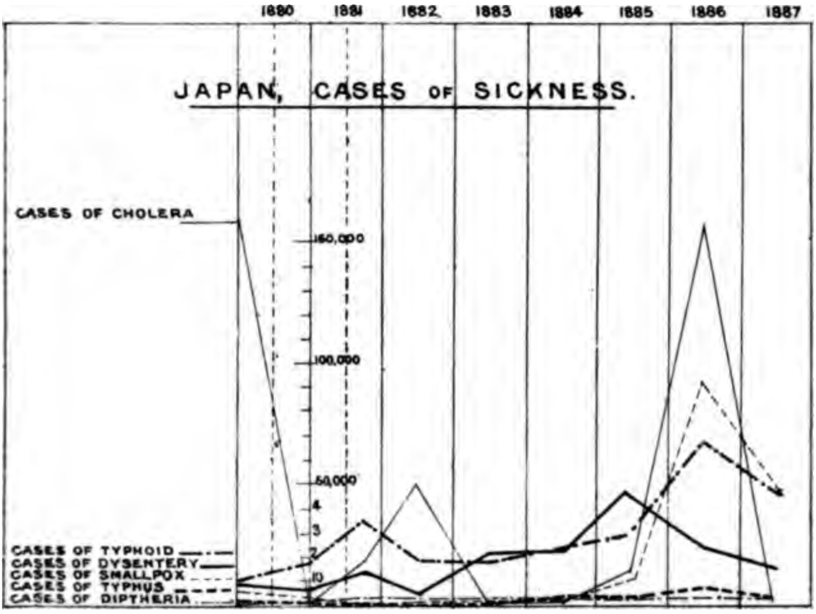

Jan. Feb. Mar. Apr. May June July Aug. Sep. Oct. Nov. Dec.
CROYDON MORTALITY.
FEVER
SCARLET FEVER
SMALL POX
DIPHTHERIA
SCALE. DIPHTHERIA, SMALL POX, SCARLET FEVER, FEVER
150 125 100 75 50 25

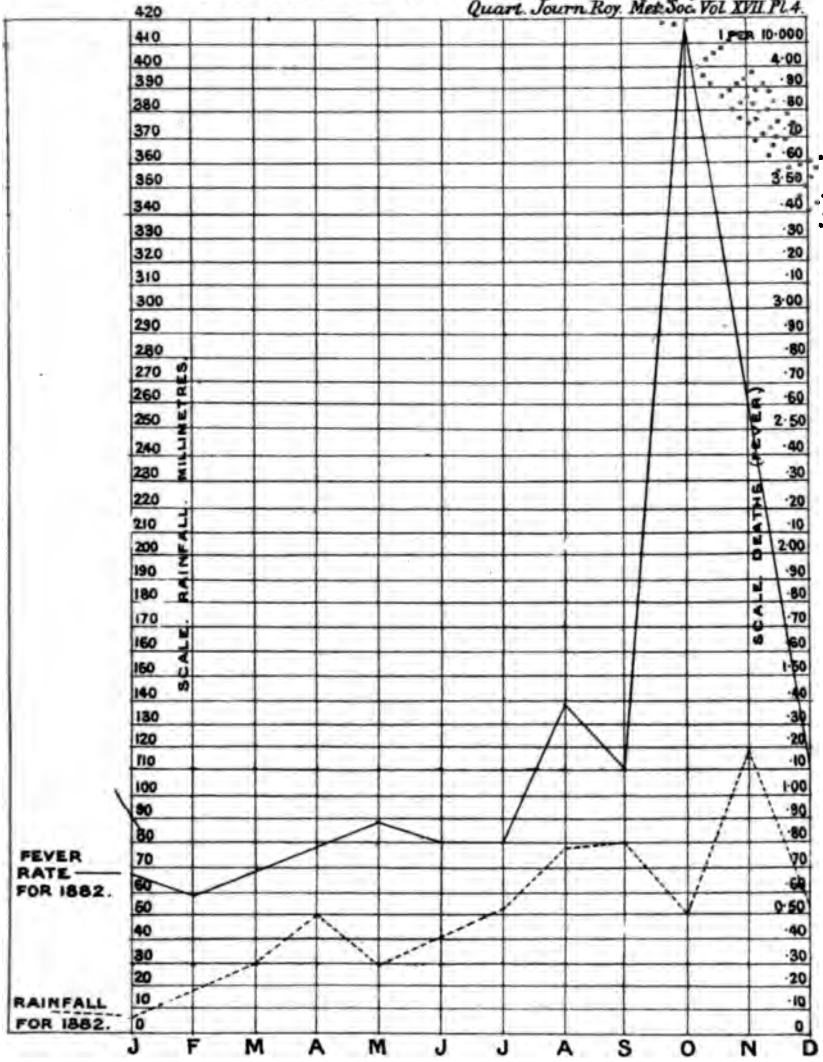

Jan. Feb. Mar. Apr. May June July Aug. Sep. Oct. Nov. Dec.
CROYDON MORTALITY WITH
PERCOLATION, APSLEY MILL AND CROYDON,
AND DARK HOURS.
TOTAL DEATHS
DEATHS LESS DIARRHŒA
PERCOLATION CROYDON
PERCOLATION APSLEY MILL
& ZYMOTIC DISEASES
HOURS OF DARKNESS
SCALE. TOTAL DEATHS & DEATHS LESS DIARRHŒA
50 45 40 35 30 25 20 15
1·3 1·2 1·1 1·00 ·9 ·8 ·7 ·6 ·5 ·4 ·3 ·2 ·1


HIGH AND LOW WATER AND CROYDON MORTALITY.
SCALE PROPORTIONAL DEATH.
DEATHS UNDER FIVE YEARS LESS DIARRHŒA
PROPORTIONAL DEATH RATE
HIGH WATER WICKHAM COURT WELL
LOW WATER MINIMUM QUANTITY FLOWING OFF CROYDON DRAINAGE
WICKHAM COURT WELL
SCALE. DEATH. CHILDREN.
SCALE. CROYDON DRAINAGE AREA.
FEET
1873 1874 1875 1876 1877 1878 1879 1880 1881 1882 1883 1884 1885 1886 1887 1888 1889

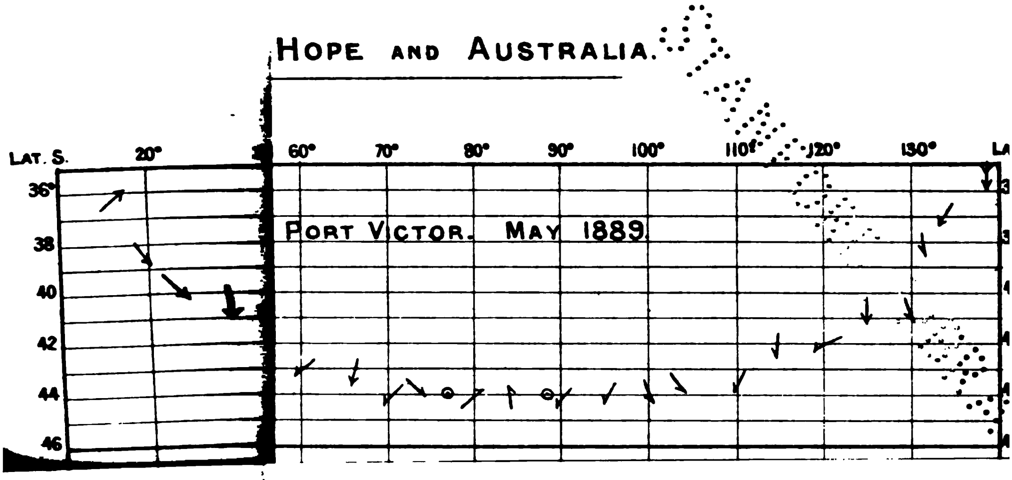

1880 1881 1882 1883 1884 1885 1886 1887
JAPAN, CASES OF SICKNESS.
CASES OF CHOLERA
150,000
100,000
50,000
CASES OF TYPHOID
CASES OF DYSENTERY
CASES OF SMALLPOX
CASES OF TYPHUS
CASES OF DIPTHERIA

PARIS.
RAINFALL AND TYPHOID FEVER.

Quart. Journ. Roy. Met. Soc. Vol. XVII. Pl. 4.



HOPE AND AUSTRALIA.



QUARTERLY JOURNAL

OF THE

ROYAL METEOROLOGICAL SOCIETY.

VOL. XVII. APRIL 1891. No. 78.

REPORT OF THE COUNCIL

FOR THE YEAR 1890.

THE progress of the Society during the year has been satisfactory, as the Papers have been of good quality and sufficiently numerous, the number of Fellows has increased, and the income, although somewhat less than in 1889, was considerably more than £1,000. The expenditure was, however, in excess of the income, owing to the whole cost of the Catalogue being charged against this one year. The ordinary office work, including the reduction and publication of the returns from the Society's stations, has been carried on with regularity, as well as the continued discussion of the phenomena attendant on the thunderstorm records for 1888-89.

New Premises Fund.—In the Report for the year 1889, the Council stated that "the rooms occupied by the Society have been whitewashed, painted, and repaired, and other improvements made in the accommodation, but this is insufficient for our wants. A Committee has been therefore appointed to make inquiries in the neighbourhood, but the rent asked for suitable rooms was too high. In these circumstances the Council have initiated a New Premises Fund, by investing the sum of £50 as a commencement towards the amount necessary to provide better accommodation. The Council hope that many of the Fellows will assist in carrying out this scheme." In 1890 a further sum of £50 was contributed by the Society. Circulars were sent out to all the Fellows, and a considerable number, as per annexed list, have responded liberally, including the President, who has assisted with £52 10s., the late President, Dr. Marcet, with £50, and Dr. C. T. Williams with £100. The total promised, including the £100 from the Society's funds, amounted to £1,110 18s., of which sum £911 1s. has been paid. This sum is inadequate to the purchase of a long lease of suitable premises, but subscrip-

tions have not yet been received from all the Fellows. The interest upon the sum already received, when added to the amount now paid for rent, with the £50 which it is hoped will be annually contributed from the Society's funds, will enable the Council to take rooms more worthy of the Society, and this they expect to do shortly.

New Catalogue of Library.—The Council referred in the Report for 1889 to the preparation of a new Catalogue of the Library, which was very necessary, inasmuch as the last Catalogue was compiled in 1876, and since that year a very considerable number of new works had been presented to or purchased by the Society. The hope was expressed that it would be completed in 1890, and that it would be creditable to the Society and useful to meteorologists. The Catalogue has been printed and bound and circulated gratis to every Fellow, at a cost of about £250. This has been a heavy charge on the Society's finances for the year, as the whole amount has been paid out of income.

Committees.—The following Committees were appointed as usual:—

General Purposes Committee.—The President, Secretaries, Foreign Secretary, Treasurer, Messrs. Bayard, Brewin, Ellis, Marcet, and Williams.

Editing Committee.—Messrs. Blanford, Inwards, and Scott.

Standing Referee on Papers.—Mr. Ellis.

Annual Exhibition Committee.—The President, Secretaries, Messrs. Bayard, Ellis, Scott, and Strachan.

Wind Force Committee.—The President, Secretaries, Messrs. Chatterton, Dines, C. Harding, Laughton, Munro, and Scott; with Mr. Whipple representing the Kew Committee.

Thunderstorm Committee.—The President, Secretaries, Messrs. Abercromby, Beaufort, Blanford, Ellis, Inwards, and Scott.

The Library Catalogue Committee.—Messrs. Eaton, Scott, and Symons, with Mr. J. S. Harding, Junr., as Editor.

Annual Exhibition of Instruments.—The Committee for arranging the Exhibition held several meetings, and eventually brought together a very good collection of instruments illustrating the application of photography to meteorology, and of photographs, &c., which were shown in the Library of the Institution of Civil Engineers. The subject was chosen as usual by the Council, and there were 96 exhibits, which were grouped as follows—Photographic Meteorological Instruments, 11; Instruments not previously exhibited, 8; Models, 4; Photographs and Drawings of Instruments, 26; and Photographs of Meteorological Phenomena, 47.

Thunderstorm Committee.—As the whole of the funds specially granted by the Royal Society for continuing the discussion of the Thunderstorms of 1888 and 1889 was spent in the early part of the year, application was made by Dr. Tripe for a further vote of £30 towards that object, which was granted in July. The times of first thunder (or of sheet lightning) for these years have all been extracted from the forms, tabulated and plotted on maps, in addition to the times of the occurrence of hail and of damage by lightning. The Committee also decided on having diagrams prepared showing the shape, path, cloud-motion, etc., of thunderstorms in the south-eastern portion

of England, *i.e.* south of 52° N., and east of 2° W. These are, as far as practicable, being prepared by Mr. Marriott as a special investigation, the cost of which will be paid out of the grant.

Inspection of Stations.—All the stations north of Lat. 52° N., which were not inspected in 1889, were visited this year, at a cost of £49 14s. 2d., towards which the Meteorological Office contributed as usual the sum of £25. Mr. Marriott reported that the stations, as a whole, were in a very satisfactory condition, the observers taking great interest in their work. These visits are considered to be of great importance, as observers often do not notice the growth of trees, &c. in the vicinity of the instruments, and the effects they have on the exposure; and the observers greatly value the inspections. The changes in the zeros of the thermometers were not so large as those found during last year's inspections. The dry and wet bulb thermometers, as well as the maximum, all mercurial, had risen in some instances as much as 0°·4, whilst the minimum (spirit thermometers) had gone down 0°·2 and 0°·3 in five instances each. Mr. Marriott's report will be found in Appendix III. (p. 58).

Discussion and Working-up Observations.—The Council have long felt that their main object was not, as many suppose, the aggregation of an immense number of returns and their publication in the *Meteorological Record;* and they have from time to time taken into consideration the necessity for working up and discussing the observations made at the Society's stations. Part of this work has already been done in the Society's office, and Mr. Bayard has kindly undertaken the discussion of the observations for the ten years 1881-90, which, when completed, will be a valuable addition to the Society's work, and justify to a great extent the time and money spent in obtaining, comparing, and reducing the records of the climatological stations.

Alterations in Stations.—The alterations in the Stations have been more numerous than usual this year. Observations have been discontinued at Cramlington and Oakamoor, whilst they have been accepted from Chelmsford; Cromer; Great Malvern; Great Thurlow, Suffolk; Lynsted, near Sittingbourne; Portsmouth; Rothbury; South Molton; Tunbridge Wells; and Wryde, near Peterborough. Observations from these stations will add considerably to the value of the *Meteorological Record,* and can be published without making any increase in the number of its pages.

Wind Force Committee.—In May last this Committee reported, and the Council adopted the Report, that in their opinion simultaneous experiments should, if possible, be carried out with the following instruments:—Robinson's Anemometer, Kew Pattern; Richard's; Dines' Helicoid; Air Meters; Pressure Plates; Tube Anemometers; and Bridled Anemometers. The Committee further reported that until the foregoing experiments had been made, they were not prepared to recommend a mode of wind measurement. The Council refer with much satisfaction to the Paper published by Mr. Dines in the *Journal* on the results of his experiments on Wind Force.

Phenological Observations.—Mr. Mawley, after consulting some of the most experienced of the Society's past and present observers, and others

interested in the subject, presented a Report to the Council, suggesting that more valuable results would be likely to be obtained if the number of plants, &c., to be observed were considerably reduced. This Report having received the approval of the Council, new observation forms have been drawn up and printed for the future use of the observers. The Council hope that the reduction in the number of plants will enable the number of observers to be increased, which will greatly strengthen, and add to the value of, the annual reports.

The list of *Publications* for which the *Journal* or *Record* is given in exchange was carefully revised during the year, and the Council believe that the exchange is favourable to the Society, as numerous publications of Foreign Meteorological Observatories and Societies are thus secured, which could not otherwise easily be obtained.

The *Library* has been considerably improved during the year, not only by the addition of new books, but also of new shelves in it, as, in spite of the withdrawal of a number of non-meteorological books for presentation to Societies dealing with the subjects on which they treated, the shelf room was and is still most inadequate.

The *Meetings* have been very well attended during the year, and the discussions well sustained and fully up to the usual mark. If the attendance of the Fellows is to be taken as evidence of the vitality of the Society, as well as of increasing interest in Meteorology, the Council feel satisfied with the result of their labours.

The usual Table, showing the changes in the number of Fellows on the roll, is now presented, and shows that, although there has been a loss of 11 by death, including one Honorary Member, and 24 from other causes, yet the total is 6 above the number on December 31st, 1889.

Fellows.	Annual.	Life.	Honorary.	Total.
1889, December 31st...	401	131	17	549
Since elected	+39	+ 2	...	+41
Since compounded	− 1	+ 1	...	0
Deceased..................	− 9	− 1	−1	−11
Retired	−14	...	...	−14
Lapsed	− 3	...	...	− 3
Defaulters	− 7	...	...	− 7
1890, December 31st...	406	133	16	555

Deaths.—The Council have to announce with much regret the deaths of ten Fellows and one Honorary Member. The names are:—

Charles Octavus Budd, M.A.	elected	Apr. 16, 1873.
Dr. C. H. D. Buys Ballot	,,	June 17, 1874.
Thomas Henry Davis	,,	Feb. 21, 1866.
William White Day, M.D.	,,	Dec. 21, 1887.

Prof. Samuel Alexander Hill, B.Sc.	elected Feb. 20, 1884.
William Henry Paine, M.D.	" Nov. 28, 1854.
Pickering Phipps, J.P.	" Jan. 15, 1879.
Sir Warington W. Smyth, M.A., F.R.S.	" Mar. 25, 1855.
Admiral Sir Bartholomew James Sulivan, K.C.B.	" Mar. 16, 1882.
Robert Tennent, F.R.S.E.	" Nov. 20, 1878.
John Harrison Walker, L.R.C.P.	" Jan. 18, 1888.

Finance.—Allowing for the expense of the Library Catalogue and the donation to the New Premises Fund as before-mentioned, the Council consider the financial state of the Society as satisfactory.

APPENDIX I.

Subscriptions promised towards the New Premises Fund,

JANUARY 21st, 1891.

	£	s.	d
Royal Meteorological Society...	100	0	0
Mr. E. G. Aldridge	1	0	0
Mr. E. B. W. Balme	2	2	0
Dr. R. Barnes	10	10	0
Mr. R. H. Barnes, B.A., F.L.S. (in three years)	3	3	0
Mr. L. L. T. Bateman	2	2	0
Mr. F. C. Bayard, LL.M.	10	10	0
Mr. W. M. Beaufort, F.R.A.S.	10	10	0
Mr. R. Bentley, F.R.G.S.	5	5	0
Mr. C. E. de Bertodano	5	0	0
Mr. T. N. Blake	2	2	0
Mr. H. F. Blanford, F.R.S....	10	10	0
Capt. E. G. Bourke, R.N.	2	0	0
Mr. W. L. Bourke, Assoc.M.Inst.C.E.	1	1	0
Mr. A. Brewin	10	10	0
Miss W. L. Brodie-Hall	1	1	0
Mr. C. J. Bromhead	5	5	0
Miss E. Brooke	25	0	0
Mr. E. H. S. Bruce, M.A.	1	0	0
Mr. F. C. Capel	10	0	0
Capt. A. Carpenter, R.N.	1	0	0
Mr. J. B. Charlesworth	20	0	0
Mr. A. W. Clayden, M.A., F.G.S.	5	5	0
Mr. J. Cleminson, M.Inst.C.E.	10	0	0
Maj-Gen. H. Clerk, R.A., F.R.S.	10	0	0
Mr. R. Cooke	10	10	0
Mr. W. S. Crimp, Assoc.M.Inst.C.E.	5	5	0
Mr. O. B. Cuvilje, F.C.A.	3	3	0
Mr. W. H. Dines, B.A.	2	0	0
Mr. J. Dover, B.A.	0	5	0
Mr. E. T. Dowson	9	0	0
Mr. P. Doyle, F.S.S.	3	3	0
Mr. E. E. Dymond, J.P.	10	10	0
Mr. E. M. Eaton, Assoc.M.Inst.C.E....	5	5	0
Carried forward	£313	17	0

	£	s.	d.
Brought forward	313	17	0
Right Hon. Lord Ebury ...	10	10	0
Mr. F. B. Edmonds ...	10	0	0
Mr. W. Ellis, F.R.A.S. ...	5	0	0
Mr. Franklen G. Evans, J.P., F.R.A.S. ...	1	1	0
Mr. F. H. D. Eyre ...	1	0	0
Mr. C. C. Farr, B.Sc. ...	2	2	0
Mr. R. Field, B.A., M.Inst.C.E. ...	21	0	0
Mr. E. E. Glyde ...	2	0	0
Mr. F. Green, M.A. ...	10	0	0
Mr. W. Friese Greene (in two years) ...	10	10	0
Capt. W. N. Greenwood ...	1	1	0
Dr. T. E. Hale, B.A. ...	1	1	0
Mr. A. J. Hands ...	2	0	0
Mr. W. J. Harris, M.R.C.S. ...	5	5	0
Mr. R. Heap, M.A. ...	10	10	0
Capt. C. M. W. Hepworth ...	1	1	0
Mr. J. J. Hicks ...	5	5	0
Mr. J. Hill, M.Inst.C.E. ...	2	2	0
Mr. H. T. Hodgson, J.P. ...	2	0	0
Mr. J. Hopkinson, F.G.S. ...	5	5	0
Mr. H. Horncastle ...	2	2	0
Mr. W. D. Howard, F.I.C. ...	10	10	0
Mr. J. Hunter, Assoc.M.Inst.C.E. (in three years) ...	9	9	0
Lieut.-Col. H. S. Knight, F.R.A.S. ...	1	1	0
Mr. J. R. Knight ...	10	10	0
Mr. Baldwin Latham, M.Inst.C.E. ...	52	10	0
Dr. R. Lawson, F.S.S. ...	10	0	0
Mr. G. J. Lee, F.R.M.S. ...	1	1	0
Mr. R. C. Cann Lippincott ...	1	0	0
Mr. L. W. Longstaff, F.R.G.S. ...	25	0	0
Capt. J. P. Maclear, R.N., F.R.G.S. ...	10	10	0
Mr. J. Mansergh, M.Inst.C.E. ...	10	10	0
Dr W. Marcet, F.R.S. ...	50	0	0
Mr. H. J. Marten, M.Inst.C.E. ...	10	10	0
Admiral T. L. Massie ...	4	1	0
Mr. E. Mawley, F.R.H.S. ...	5	5	0
Mr. H. Mellish, J.P. ...	10	10	0
Dr. J. W. Moore ...	1	0	0
Mr. R. T. Morgan ...	1	1	0
Mr. L. P. Muirhead (in three years) ...	3	3	0
Mr. C. E. Mumford ...	2	0	0
Mr. R. W. Munro ...	4	4	0
Messrs. Negretti and Zambra ...	10	10	0
Mr. T. H. G. Newton, M.A., J.P. ...	5	0	0
Dr. G. Oliver ...	5	0	0
Miss E. A. Ormerod ...	10	10	0
Mr. A. F. Osler, F.R.S. ...	25	0	0
Rev. J. D. Parker, LL.D. ...	10	10	0
Mr. J. Parnell, F.R.A.S. ...	10	10	0
Mr. A. A. Pearson ...	1	0	0
Mr. C. N. Pearson ...	1	1	0
Mr. C. E. Peek, M.A., F.R.G.S. ...	5	0	0
Mr. H. Perigal, F.R.A.S. ...	10	10	0
Mr. F. H. Phillips ...	2	0	0
Mr. C. M. Powell ...	5	0	0
Mr. A. W. Preston ...	1	1	0
Mr. C. L. Prince, M.R.C.S., F.R.A.S. ...	3	3	0
Dr. W. T. Radford, F.R.A.S. ...	10	0	0
Carried forward	£774	2	0

	£	s.	d.
Brought forward	774	2	0
Mr. A. Rapkin	2	2	0
Capt. H. E. Rawson, R.E.	2	2	0
Mr. T. F. Read (in five years)	5	5	0
Mr. C. R. Rivington	5	5	0
Dr. J. Robb	1	1	0
Mr. J. Rose-Innes, B.A., B.Sc.	1	10	0
Mr. A. L. Rotch, B.Sc.	5	0	0
Sir D. L. Salomons, Bart.	10	0	0
Mr. R. H. Scott, F.R.S. (in two years)	10	10	0
Mr. S. W. Silver, F.R.G.S.	10	10	0
Mr. J. G. Single, M.Inst.C.E.	5	0	0
Dr. F. G. Smart	10	10	0
Mr. E. J. C. Smith	0	10	6
Mr. H. Smith	2	2	0
Mr. R. T. Smith, M.Inst.C.E.	2	0	0
Mr. H. S. Snell, F.R.I.B.A.	10	10	0
Mr. H. Southall	10	10	0
Mr. W. F. Stanley, F.G.S.	5	0	0
Rev. C. J. Steward, M.A.	1	0	0
Lieut.-Gen. R. Strachey, R.E., F.R.S.	10	0	0
Mr. R. F. Sturge	2	2	0
Mr. G. J. Symons, F.R.S.	10	10	0
Mr. H. S. Tabor (in three years)	6	6	0
Rev. C. J. Taylor, F.R.A.S.	2	2	0
Dr. H. C. Taylor, J.P.	2	0	0
Mr. E. H. Ryan Tenison, M.R.C.S.	0	10	6
Mr. S. Tomlinson, Assoc.M.Inst.C.E. (in two years)	10	10	0
Capt. H. Toynbee, F.R.A.S.	2	10	0
Dr. J. W. Tripe (in two years)	10	10	0
Mr. W. B. Tripp, M.Inst.C.E.	1	1	0
Capt. S. Trott	10	10	0
Mr. W. H. Tyndall (in two years)	10	10	0
Mr. R. Tyrer, B.A.	1	0	0
Mr. B. C. Wainwright	10	10	0
Mr. H. S. Wallis	1	1	0
Dr. J. Walther	2	2	0
Capt. W. Watson	5	5	0
Mr. B. I. Whitaker, J.P.	5	5	0
Mr. G. M. Whipple, B.Sc. F.R.A.S.	2	0	0
Dr. C. T. Williams, M.A.	100	0	0
Mr. T. Wilson (in two years)	10	10	0
Mr. E. Woods, M.Inst.C.E....	10	10	0
Mr. H. Wortham, F.R.A.S....	2	2	0
Mr. P. Wright, F.C.S.	5	0	0
Col. W. S. Young	2	2	0
	£1110	18	0

APPEN-

STATEMENT OF RECEIPTS AND EXPENDITURE

Receipts.

	£	s.	d.	£	s.	d.
Balance from 1889				416	5	10
Subscriptions for 1890	671	11	11			
Do, former years	26	4	0			
Do, paid in advance	35	2	0			
Life Compositions	63	0	0			
Entrance Fees	54	0	0			
				849	17	11
Meteorological Office—Copies of Returns	120	12	1			
Do. Grant towards Inspection Expenses	25	0	0			
				145	12	1
Dividends on Stock				63	5	0
Sale of Publications				33	0	8
Grant for Thunderstorm Inquiry				30	0	0
New Premises Fund—Contributions of Fellows	750	7	0			
Interest on Investment	4	1	3			
				754	8	3
				£2292	9	9

DIX II.

FOR THE YEAR ENDING DECEMBER 31ST, 1890.

PAYMENTS.

	£ s. d.	£ s. d.
Journal, &c.:—		
Printing, Nos. 73 to 76	128 17 6	
Illustrations	21 19 6	
Authors' Copies	13 18 0	
Meteorological Record, Nos. 35 to 38	50 1 0	
Registrar-General's Reports	8 8 0	
		223 4 0
Printing, &c.:—		
General Printing	33 0 0	
List of Fellows	9 12 6	
Library Catalogue	243 10 0	
Stationery	13 15 11	
Books and Bookbinding	19 7 9	
		319 6 2
Office Expenses:—		
Salaries	343 0 0	
Rent and Housekeeper	48 7 0	
Furniture, Repairs, Coals, &c.	22 4 4	
Postage	64 16 1	
Petty Expenses	9 11 2	
Refreshments at Meetings	14 4 0	
Exhibition of Instruments	8 4 7	
		510 7 2
Observations:—		
Inspection of Stations	49 14 2	
Observers at Old Street and Seathwaite	7 2 0	
Instruments	2 5 0	
Thunderstorm Discussion	11 14 0	
		70 15 2
Stock:—		
Purchase of £54 18s. N. S. W. 4 per cent. Stock		63 0 0
New Premises Fund:—		
Investment of Contributions (including Grant by the Society of £50)		766 17 3
		1953 9 9
Balance:—		
At Bank (including £37 11s., balance of New Premises Fund)	319 10 4	
In hands of the Assistant-Secretary	19 9 8	
		339 0 0
		£2292 9 9

Examined and compared with the Vouchers, and found correct,

J. S. HARDING, JUNR., H. SOWERBY WALLIS, } *Auditors.*

January 14th, 1891.

APPEN-

ASSETS AND LIABILITIES

Liabilities.

	£	s.	d.
To Subscriptions paid in advance	35	2	0
„ Grant for Thunderstorm Inquiry, unexpended	26	14	6
„ New Premises Fund	858	8	11
	920	5	5
„ Excess[1] of Assets over Liabilities	2492	0	5
	£3412	5	10

1 This excess is exclusive of the value of the Library and Stock of Publications.

NEW PRE-

	£	s.	d.	£	s.	d.
Balance :—						
Purchase of £51 5s. 8d. Consols, 1889	50	0	0			
„ £800 0s. 0d. „ 1890	766	17	3			
				816	17	3
Cash in Bank				41	11	8
				£858	8	11

DIX II.—Continued.

ON JANUARY 1st, 1891.

ASSETS.

	£ s. d.	£ s. d.
By Investment in M. S. and L. R. 4½ Debenture Stock, £800 at 138	1104 0 0	
„ Investment in N. S. W. 4 per cent. Inscribed Stock, £654 18s. at 114½	749 17 2	
„ Investment in 2¾ per cent. Consols, £250 at 95¾	239 7 6	
„ New Premises Fund.—Investment in 2¾ per cent. Consols, £851 5s. 8d. at 95¾	815 2 0	
		2908 6 8
„ Subscriptions unpaid, estimated at	25 0 0	
„ Entrance Fees unpaid	5 0 0	
„ Interest on Stock	34 19 2	
		64 19 2
„ Furniture, Fittings, &c.	35 0 0	
„ Instruments	65 0 0	
		100 0 0
„ Cash in hands of Bank of England (including £37 11s. balance of New Premises Fund)	319 10 4	
„ Cash in hands of Assistant Secretary	19 9 8	
		339 0 0
		£3412 5 10

J. S. HARDING, Junr., H. SOWERBY WALLIS, } *Auditors.*

WILLIAM MARRIOTT, *Assistant Secretary.*

January 14th, 1891.

MISES FUND.

	£ s. d.	£ s. d.
Grant by the Society, 1889	50 0 0	
„ „ „ 1890	50 0 0	
		100 0 0
Contributions of Fellows, 1890		750 7 0
Interest to October 5th, 1890	4 1 3	
„ January 5th, 1891	4 0 8	
		8 1 11
		£858 8 11

J. S. HARDING, Junr., H. SOWERBY WALLIS, } *Auditors.*

WILLIAM MARRIOTT, *Assistant Secretary.*

January 14th, 1891.

APPENDIX III.

INSPECTION OF THE STATIONS, 1890.

I have visited all the stations north of Lat. 52°N. which were not inspected last year. The stations, on the whole, were in a very satisfactory condition, the observers taking great interest in the work. As I call upon the observers without previous notice, I am able to see the stations in their normal condition.

These visits are of great service, as the observers do not always notice the growth of trees, &c. in the vicinity of the instruments, and the effect which these may have upon the exposure. The observers also greatly value the visits, as they look upon them as some recognition of their services to the Society.

The changes in the zeros of the thermometers were not so large as those found in the instruments during last year's inspection. The changes were as follows :—

Dry.	Wet.	Max.	Min.	Earth.
4 risen 0°·1	4 risen 0°·1	3 risen 0°·1	5 gone down 0°·2	1 risen 0°·3
1 „ 0·2	1 „ 0·2	2 „ 0·3	5 „ 0·3	
1 „ 0·4	1 „ 0·4			

These changes show that the zeros of mercurial thermometers continue to rise, and of spirit thermometers to sink, with age.

The photographs of the stations which have been taken during the present inspection are not so good as those taken last year, the weather at the time of my visits being often wet and unfavourable for photography.

William Marriott.

October 15th, 1890.

NOTES ON THE STATIONS.

Aspley Guise, *September 10th.*—The thermometer screen, rain gauge, and solar and grass thermometers were moved in May 1890 some distance east-south-east of the former site, which had become much sheltered by the growth of trees. The minimum thermometer had 0°·7 of spirit at the top of the tube.

Belper, *August 15th.*—The thermometer screen is somewhat shaded by a tree. On testing the thermometers it was found that the maximum had gone up 0°·3, and the wet 0°·1.

Blackpool, *August 19th.*—This station was not in a satisfactory condition. The acting observer had only been in charge a few months, and had received little or no instruction as to the reading of the instruments, &c. The rain gauge was not properly fixed in the ground. The thermometer screen required painting. The minimum thermometer had been broken the day before my visit. The sunshine recorder, which is placed on the roof of the Pavilion at the end of the Pier, required adjusting, as the trace was not parallel with the lines on the card.

BOLTON, *August 18th.*—This station was in good order. The anemometer had been mounted on a pole in the meteorological enclosure, and appeared to be working well. The sunshine recorder required to be made a fixture. The dry-bulb had gone up 0°·1, and the one foot earth thermometer 0°·3.

BURTON-ON-TRENT, *August 12th.*—The instruments are placed in an enclosure surrounded by iron railings in a field on the south side of St. Paul's Square. The exposure is very open. The rain gauge was too near the thermometer screen, and required to be moved about 8 feet further to the southwest. The muslin on the wet bulb required changing. Mr. Wells has a hollow cylinder bulb grass minimum thermometer which reads 4° lower than when first obtained.

BUXTON, *August 15th.*—The instruments were in good order. The maximum thermometer, which some months previously had lost its index, was working all right, the index having been set right by the maker.

CHEADLE, *August 14th.*—This station was in good order. Two trees on the north-east and south-east of the rain gauge are growing up, and will soon make too great an angle with the gauge. The grass minimum thermometer had a little spirit at the top of the tube.

CROMER, *July 24th.*—I called on Mr. Sandford for the thermometers which had been used by Mr. Cooper. After some conversation Mr. Sandford agreed to continue the observations if a set of instruments were lent by the Society. I selected a fresh site for the thermometer screen, the former site being objected to as being too conspicuous. The rain gauge will be better exposed than formerly.

DRIFFIELD, *July 19th.*—The instruments are well exposed in a large strawberry garden. The ground is nearly flat, but rises slightly from south to north. The sub-soil is clay on chalk. The station was in good order.

GREAT THURLOW, *September 11th.*—This station is in the valley of the Stour, four miles north of Haverhill, and ten miles south-south-east of Newmarket. The ground is undulating in the district. The thermometer screen is placed on the lawn of Hill House. The rain gauge is on the lawn of the Hall. The instruments were in good order.

HARROGATE, *July 15th.*—The instruments were in the same position as formerly, in the private grounds at West End Park. The maximum thermometer had gone up 0°·1. Mr. Wilson had procured a new verified set of instruments which were to be placed in the Bog Valley Gardens, where the ground slopes from the north-west to the south-east. A Jordan sunshine recorder will also be put up.

HILLINGTON, *July 24th.*—The thermometers were all correct except the grass minimum, which had gone down 0°·3.

HODSOCK, *August 29th.*—This station was in good order, and the thermometers all correct.

KENILWORTH, *August 12th.*—The minimum thermometer had gone down 0°·3, otherwise the instruments were in good order.

KIRKLAND, *August 23rd.*—This station was organised in connection with the Helm Wind Inquiry. Only the dry bulb and the thermograph are in the

screen. The thermograph was not working very satisfactorily. On testing the thermometers it was found that the dry and wet had both gone up 0°·1.

LINCOLN, *July 22nd.*—The electrical thermometer appeared to be working satisfactorily. Two of the zincs in the battery were much worn, and would shortly require to be renewed. The screen for the electrical and check thermometers was to be painted the next time the painters were on the tower. The wet and the check thermometers had both gone up 0°·1, and the minimum had gone down 0°·2. The rain gauge required a little soldering.

LOWESTOFT, *July 25th.*—The observations are taken by Mrs. Miller, as Mr. Miller is away the greater part of the year. The minimum thermometer had gone down 0°·2. The 1 foot and 2 feet earth thermometers have long tubes enclosed in wooden cases, and could not consequently be compared. The tubes are not graduated.

MACCLESFIELD, *August 16th.*—The thermometers were all correct except the minimum, which had 0°·5 of spirit up the tube. The thermometer screen required repairing and painting.

MALVERN, *August 11th.*—The thermometer screen is placed in a terraced garden, at the back of Belle Vue Terrace, and at the foot of the Malvern Hills. The rain gauge is on a wall. Considering the surroundings, the exposure of the instruments is fairly good. The dry had gone up 0°·6, and the wet 0°·5.

NEWTON-REIGNY, *August 22nd.*—This station was in good order. The maximum thermometer had gone up 0°·1. I could not test the earth thermometers as they had long tubes buried in the soil.

ROTHBURY, *July 17th.*—I called on Mr. Bertram, the bailiff of Lord Armstrong, with the view of getting a station organised at Cragside. I also saw Lord Armstrong, who agreed to equip a climatological station. I selected a site for the thermometer screen in an open situation. The rain gauge, which had been in use for some years, was in good condition. I visited this place again on August 26th, the day after the thermometer screen had been erected, and the instruments put in position.

ROUNTON, *July 16th.*—The thermometer screen required painting. The maximum had gone up 0°·3, and the grass minimum had gone down 0°·3. I instructed the observer as to the management of the wet bulb during frost.

SCALEBY, *August 25th.*—The wet bulb thermometer was not working correctly. After being properly wetted, the thermometer read 3°·4 lower than previously. The minimum thermometer had gone down 0°·2.

SCARBOROUGH, *July 18th.*—The muslin and cotton on the wet bulb were not in working order. The thermometer screen required painting. I recommended that the position of the thermometers in the screen should be re-arranged, and also that the currant bushes round the screen should be cut down. On comparing the thermometers, it was found that the wet and the maximum had both gone up 0°·1, and that the minimum had gone down 0°·3.

SEATHWAITE, *August 21st.*—This station was in good order. The dry had gone up 0°·1. As the index of the Phillips' maximum had got into the bulb, I brought the thermometer away with me, there still being a Negretti maximum left.

SOMERLEYTON, *July 25th.*—All the instruments were in good order except the minimum, which had some spirit at the top of the tube.

SOUTHWELL, *August 28th.*—This station was in good order. On comparing the thermometers it was found that the minimum had gone down 0°·2.

SUTTON COLDFIELD, *August 13th.*—The Jordan sunshine recorder is mounted on the turret of the Town Hall, and has a free exposure. Mr. Marston has also a set of instruments in his garden, and takes regular Second Order observations.

TUNBRIDGE WELLS, *December 19th.*—This station is on Mount Ephraim, about the highest part of Tunbridge Wells. The station was in good order. The sunshine recorder is mounted on the south corner of the tower of the house, and has an excellent exposure. On comparing the thermometers it was found that the dry had gone up 0°·6 and the wet 0°·5.

USHAW, *July 16th.*—This station was in good order.

WAKEFIELD, *July 14th.*—The thermometer screen required painting, and the fastening of the door to be altered. The funnel of the rain gauge needed soldering. The muslin on the wet bulb was dirty.

WINDERMERE, *August 20th.*—The Rev. T. Mackereth has put up his instruments in his yard, which is somewhat confined. He has, however, made the best of the circumstances, and will no doubt get very fair results. On comparing the thermometers it was found that the maximum had gone up 0°·3, and that the minimum had gone down 0°·2. I also saw the Jordan sunshine recorder, which is mounted on the roof of the Hydropathic Hotel at Bowness; the exposure is very good.

WRYDE, *July 23rd.*—I called on Mr. Egar to inquire whether he would equip his station so as to fulfil the Society's requirements. This he agreed to do. I selected a fresh site for the instruments, as the existing one was rather confined. I visited this station again on September 4th, and saw the instruments in their new position. The exposure is very good. On comparing the thermometers it was found that the dry and wet had both gone up 0°·2.

APPENDIX IV.

OBITUARY NOTICES.

DR. CHRISTOPHER HENRY DIDERICUS BUYS BALLOT, who died February 3rd, 1890, in the 73rd year of his age, was born at Kloetingen, where his father was a Pastor in the Reformed Church of Holland. He went to the University of Utrecht at the age of 18, and took out his Doctor's Degree in 1844. His thesis was *de Synaphia et Prosaphia.* Next year he was appointed "Docent" in Mineralogy and Geology, soon after Professor of Mathematics, and subsequently Professor of Experimental Physics, a post which he held till 1887, when, according to the Dutch law, he had to retire after 40 years' service in the chair.

As to his lectures they were full of new ideas, many of them far in advance

of his age. One of his earliest pamphlets bore the title, *A Sketch of the Physiology of Inorganic Nature*, a sufficiently startling paradox! Many of the ideas put forward by Buys Ballot in the first half of this century are now being adopted as scientific truths on the authorities of Maxwell and Clausius.

His connection with Meteorology began in 1849. He fitted up at his own expense a cellar in the Sonnenborgh, at Utrecht, for magnetic observations, and started meteorological observations above ground at the same place. The observations were made by Krecke, but discussed and published by Buys Ballot. In 1854 the establishment was taken over by the Government, and became the Royal Meteorological Institute of Utrecht. The "Law," by which he is most generally known, was popularly explained by him in the pamphlet *Eenige Regelen vom Aanstaande Weersveranderingen in Nederland, &c.*, published in 1860, which was translated by Adriani and published in England in 1863. It was Mr. Joseph Baxendell and Mr. G. V. Vernon, of Manchester, who at last, in 1867, obtained official recognition of this principle in England.

Buys Ballot in most of his investigations dealt exclusively with the variations from the mean values of the meteorological elements for each station. This enabled him to dispense with the reduction of the barometer to sea level, but this mode of treatment of observations has not met with general acceptance.

He was from the first deeply interested in Meteorological Congress work, and in international co-operation in investigations, and was an ardent advocate of the visionary scheme of an International Institute, which was broached at Vienna and at Rome.

He has left behind him the memory of one of the most modest, simple-minded and amiable of men, while the long list of his papers (41 prior to 1875 in the Royal Society Catalogue) attests his industry and marvellous ability.

He was elected an Honorary Member of the Society on June 17th, 1874.

Charles Octavus Budd was the eighth son of Samuel Budd, a medical practitioner at North Tawton, in Devonshire, and was born at North Tawton in the month of July 1822. He entered at Pembroke College, Cambridge, in 1840, and graduated B.A. in 1844, when he was 3rd Wrangler. Shortly afterwards he was elected a Fellow of his college, and being a bachelor he retained his fellowship up to the time of his death, which occurred at Torquay on the 24th December 1890.

He belonged to a family well known in the medical profession, in which several of his brothers attained high distinction: two, the late Dr. Geo. Budd, formerly Professor of Medicine in King's College, London, and the late Dr. William Budd of Bristol, both being Fellows of the Royal Society, and deemed worthy of a place in the *Dictionary of National Biography*. In consequence of ill-health Mr. C. O. Budd was never able to follow any profession, but he was known to his friends as a man of conspicuous ability and great general culture.

He was elected a Fellow of the Society on April 16th, 1873.

Samuel Alexander Hill was the eldest son of a clergyman residing at Ballyboley, near Belfast, in the county of Antrim, and was born at that place in 1851. He received his early education in a local school, and afterwards studied in the Training School at Dublin, where he greatly distinguished himself, especially in the science classes, and gained a scholarship which enabled him to matriculate at the Royal School of Mines, and also in the London University. Having completed his three years' course in the former institution, and taken the degree of Bachelor of Science, he was offered the Professorship of Physical Science in the Muir College, Allahabad, and in 1875 he proceeded to India to take up the appointment. On his arrival he was appointed also Meteorological Reporter to the Government of the North-west Provinces, and he continued to hold these appointments conjointly up to the time of his death.

A professorship in an Indian college does not as a rule afford many facilities for original scientific research, and the climate of the Gangetic Plain is but little favourable to mental exertion, but Mr. Hill was not one of those who content themselves with discharging the merely administrative duties of their appointments, and inasmuch as his Meteorological Reportership placed at his command the data furnished by the province he so ably superintended, he speedily devoted himself to the study and discussion of these data, a task for which his knowledge of physics and mathematics peculiarly fitted him. A subject which early engaged his attention was the detection of variations in the intensity of the solar heat by means of the black-bulb thermometer *in vacuo*, and by selecting for comparison those registers only which recorded the readings of one and the same instrument, always exposed on the same spot, and applying certain corrections for the varying conditions of the atmosphere in respect of humidity, suspended dust, &c., he succeeded in demonstrating a very well-marked oscillation of the insolation temperature, having its minimum coincident with the epoch of maximum sun-spots, and *vice-versâ*. A similar oscillation has since been shown to affect the temperature of the Indian atmosphere as a whole. Two of Mr. Hill's papers on the above subject were published in the *Proceedings of the Royal Society* in 1881 and 1882, and three others in the *Journal of the Asiatic Society of Bengal* in 1883, 1884, and 1886.

Most of his more important writings were published in the *Indian Meteorological Memoirs* and the *Philosophical Transactions* of the Royal Society. The former include a very complete discussion of the climate of Allahabad, a memoir on the meteorology of the N.W. Himalaya, another on the rainfall of Benares in relation to the prevailing winds, and one on the distribution of temperature in North-western India, illustrated by monthly and annual isothermal charts of the greater part of Northern India; furthermore, two memoirs on the vertical distribution of temperature and humidity in the lowest layer of the atmosphere, and one on the temperature of the ground at small depths below the surface, and its variations from year to year.

To the *Philosophical Transactions* of 1887 he contributed a memoir on certain anomalies in the winds of Northern India, which he traced to the dis-

tribution of pressure at an elevation of 10,000 ft. above the sea level, and showed that this is entirely different in character from that given by observations on the plains. Several of his minor contributions appeared in *Nature* and the *Zeitschrift* of the Austrian Meteorological Society, and one, viz. a Criticism of Professor Langley's researches on solar heat, in the *Quarterly Journal* of this Society, of which Mr. Hill was elected a Fellow in February 1884.

Mr. Hill's treatment of the many subjects he has discussed displays much originality of conception and method, combined with strict adherence to the canons of logical reasoning, and he has contributed in no small degree to the advancement of our knowledge of Indian meteorology and incidentally to that of meteorological processes in general. Up to the day before his death there seemed no reason for misgiving that he might not continue for many years to come to add to the good work he had already accomplished. About the middle of September last he had indeed a smart attack of fever, such as is not unusual at that unhealthy season, but he appeared to be almost convalescent when, without any warning, congestion of the brain set in, and after 18 hours of unconsciousness he passed away quietly on the morning of the 23rd at the age of 38 years and 11 months.

Pickering Phipps, who was formerly Conservative Member of Parliament for the Borough of Northampton, and afterwards for South Northamptonshire, died at his residence, Collingtree, Northamptonshire, on Sunday, September 7th, aged 68. Mr. Phipps was the senior partner in the firm of Phipps and Son, Brewers, Northampton and Towcester. He was a member of the Northampton Town Council for 30 years, and was twice elected mayor of the borough.

He was elected a Fellow of this Society on January 15th, 1879.

Sir Warington W. Smyth was the eldest son of Admiral W. H. Smyth, F.R.S., and was born at Naples in 1817. He was educated at Westminster and Bedford Schools, and at Trinity College, Cambridge, where he was one of the winning University crew on the Thames in 1839. In that year he graduated and obtained a travelling Fellowship, which enabled him to devote more than four years to a journey through the chief mining districts of Europe, and thus to lay the foundation of that practical knowledge which subsequently made him the greatest British authority on mining matters. As a result of his travels through the European and Asiatic dominions of the Sultan, he published in 1854 a work entitled *A Year with the Turks*. His official career began in 1844, when he was appointed by Sir Henry de la Beche to a post on the Geological Survey, and while holding this position he explored and geologically mapped various metalliferous districts. In 1845 he joined the Geological Society, and in 1866 was elected its President. For the last 17 years he acted as Foreign Secretary, in which post his rare linguistic powers proved of great service to the Society. On the foundation of the Royal School of Mines in 1851, he was appointed the first Lecturer on Mining and Mineralogy. On the reorganisation of the School in 1881 he gave up

the chair of Mineralogy, but acted as Professor of Mining until his death. He held the office of Inspector of the Mines in the Duchy of Cornwall, and in 1857 he was also appointed Comptroller of all the mineral properties belonging to the Crown.

In 1879 a Royal Commission was appointed to inquire into accidents in mines, and the possible means of preventing their occurrence, and of limiting their disastrous consequences. Prof. Smyth was appointed chairman. The Commission ended its work in 1886, and the Report definitely settled some important questions bearing upon the diminution of accidents in mines.

To his scientific attainments Sir Warington added singular literary skill. His early classical training enabled him to write with rare elegance and vigour. As a teacher he was very popular with his pupils, his success as a lecturer being due not only to his finished delivery, but also to his skill as a draughtsman, which enabled him to dispense with the aid of elaborate diagrams, and to rely merely on accurate blackboard sketches, which he drew with great rapidity in the presence of his class. His reputation as Professor attracted to the School of Mines students from all parts of the world.

For his labours on the Accidents in Mines Commission and for his other public services he received the honour of knighthood on the occasion of Her Majesty's Jubilee. Throughout his life he refused the great pecuniary rewards offered by the commercial branches of mining, and preferred to devote the half-century during which he was engaged in business connected with mines to the service of science and of the State. Although he had been in ill-health for some time he never neglected his official duties. He died in harness, with a partially corrected examination paper on the table before him, on June 29th.

He was elected a Fellow of this Society on March 25th, 1856.

Admiral Sir Bartholomew James Sulivan was the eldest son of the late Rear-Admiral Ball Sulivan, and was born in 1810. He entered the service in 1823, and became Lieutenant in 1830. In 1841 he was promoted to the position of Commander for surveying services. He was surveying officer to the combined Paraná Expedition, from September 1845 to April 1846, at Obligado; made the plan for the attack and commanded the leading division of ships and the advance of the landing force. For this service he was promoted to Captain in 1845.

In 1848, as "Colonel and Chief of the Staff," he organised the Dockyard Volunteers. He was Surveying Captain of the Baltic Fleet throughout the war; was gazetted for services at Bomarsund in 1854, and Sveaborg in 1855; proposed, planned, and carried out under Rear-Admiral the Hon. R. S. Dundas the bombardment of Sveaborg, and obtained the Baltic medal. In 1863 he became Rear-Admiral, in 1870 Vice-Admiral, and in 1877 Admiral.

Sir B. J. Sulivan was made a C.B. in 1855 and K.C.B. in 1869. He was naval officer of the Marine Department, Board of Trade, from December 1856 to April 1865. He died at Bournemouth on New Year's Day, 1890.

He was elected a Fellow of this Society on March 16th, 1882.

APPENDIX V.

BOOKS PURCHASED DURING THE YEAR 1890.

Bigot de Morogues, P.M.S.—Mémoire historique et physique sur les chutes des pierres tombées sur la surface de la terre à diverses époques. 8vo. (1812.)

Coulvier-Gravier and Saigey.—Recherches sur les étoiles filantes. Introduction historique. 8vo. (1847.)

Cousté, —.—Théorie physico-dynamique des météores à tourbillons suivie d'un appendice sur "la défense de la loi des tempêtes" de M. Faye. 8vo. (1875.)

[Defoe, D.]—The Storm: or, a collection of the most remarkable casualties and disasters which happen'd in the late dreadful tempest, both by sea and land. 8vo. (1704.)

Dufour, L.—Notes sur le problème de la variation du climat. 8vo. (1870.)

Fournet, J.—Note sur le froid périodique du mois de Mai. 8vo. (1848.)

Grandsagne, A. de, and L. Fouché.—Manuel complet de physique et de météorologie. 2 éd. 12mo. (1835.)

Hildebrandsson, H. H., W. Köppen, and G. Neumayer. Wolken-Atlas. 4to. (1890.)

Mackenzie, G.—The system of the weather of the British Islands. 8vo. (1821.)

Medical Essays and Observations published by a Society in Edinburgh. 4th ed. 5 vols. 12mo. (1752.)

Nijné Taguilsk (Russia).—Observations météorologiques faites à Nijné-Taguilsk (Monts Oural), du 1er October 1839 au 31 Décembre 1840. 8vo. (1842.)

Official Year Book of the Scientific and Learned Societies of Great Britain and Ireland. 1890. 8vo. (1890.)

Paris, Ministère du Commerce, de l'Industrie et des Colonies.—Exposition Universelle Internationale de 1889. Direction générale de l'Exploitation. Congrès Météorologique International tenu à Paris du 19 au 26 Septembre 1889. Procès-verbaux, sommaires. Par MM. Moureaux, Lasne, l'Abbé Maze. 8vo. (1889.)

Paris, Société Météorologique de France.—Congrès Météorologique International tenu à Paris du 19 au 26 Septembre 1889. Mémoires. 8vo. (n.d.)

Reinzer, F.—Meteorologia Philosophico-Politica, in duodecim dissertationes per questiones meteorologicas, et conclusiones politicas divisa, appositisque symbolis illustrata. Folio. (1709.)

APPENDIX VI.

DONATIONS RECEIVED DURING THE YEAR 1890.

Presented by Societies, Institutions, &c.

Adelaide, Government Observatory.—Rainfall in South Australia, 1887.—Report on telegraphic determination of Australian longitudes.

Allahabad, Meteorological Office.—Annual statement of rainfall in the North-Western Provinces and Oudh, 1889.

Bayonne, Société de Climatologie Pyrénéenne.—Bulletin, 2me Anneé, Nos. 10 to 3e Année, No. 9.

Berlin, Deutsche Meteorologische Gesellschaft.—Meteorologische Zeitschrift, 1890.

Berlin, Gesellschaft für Erdkunde.—Verhandlungen, Band XVI., No. 10 to Band XVII., No. 9.—Zeitschrift, Nos. 143 to 149.

Berlin, Königlich Preussisches Meteorologisches Institut.—Ergebnisse der meteorologischen Beobachtungen im Jahre 1889, Heft 2.

Birkenhead, Liverpool Observatory.—Report of the Astronomer to the Marine Committee, Mersey Docks and Harbour Board, and results of meteorological observations made at the Observatory, 1884-8.

Bombay, Meteorological Office.—Brief Sketch of the Meteorology of the Bombay Presidency, in 1888-90.

BRISBANE, CHIEF WEATHER BUREAU.—Brisbane Observatory: Meteorological Synopsis, July 1889.—Daily Weather Charts of Australia, July 25th, 1889, to April 8th, 1890.—Summaries of Rainfall in Queensland, July to Dec. 1889.—The Queensland Meteorological Record, July to Sept. 1889.

BRISBANE, GENERAL REGISTER OFFICE.—Report on the Vital Statistics, Oct. 1889 to Sept. 1890.—Queensland Vital Statistics, 1889.

BRUSSELS, INSTITUT NATIONAL DE GÉOGRAPHIE.—Bulletin Météorologique, March 1887, and Dec. 1889 to Nov. 1890.

BRUSSELS, OBSERVATOIRE ROYAL.—Annales Astronomiques, Nouvelle Série, Tome VI.—Annales Météorologiques, Deuxième série, Tome II.—Annuaire 1890.—Bibliographie Générale de l'Astronomie. Par J. C. Houzeau et A. Lancaster. Tome 1. Part 1.

BUDAPEST, K. UNG. CENTRAL-ANSTALT FÜR METEOROLOGIE UND ERDMAGNETISMUS.—Jahrbüch 1887.

CAIRO, SOCIÉTÉ KHÉDIVIALE DE GÉOGRAPHIE.—Sommaire Historique des Travaux Géographiques exécutés en Egypt sous la Dynastie de Mohammed Aly.

CALCUTTA, METEOROLOGICAL OFFICE.—Cyclone Memoirs, Part 2. Bay of Bengal Cyclone, August 21-28, 1888.—Handbook of cyclonic storms in the Bay of Bengal, by J. Eliot.—India Daily Weather Reports, Dec. 8, 1889, to Nov. 16, 1890, and Nov. 24 to Dec. 7, 1890.—Memorandum on the snowfall in the mountain districts of Northern India and Afghanistan, and the abnormal features of the meteorology of India during Jan. to May 1890.—Report on the administration of the Meteorological Department of the Government of India in 1888-89.—Report on the Meteorology of India in 1888.

CALCUTTA, ST. XAVIER'S COLLEGE OBSERVATORY.—Meteorological Observations, July to Dec. 1889.

CAMBRIDGE, HARVARD COLLEGE OBSERVATORY.—Henry Draper Memorial. Second Annual Report of the photographic study of Stellar Spectra.

CAMBRIDGE, NEW ENGLAND METEOROLOGICAL SOCIETY.—Bulletin, Dec. 1889 to Nov. 1890.

CAPE TOWN, METEOROLOGICAL COMMISSION.—Report, 1889.

CHEMNITZ, KÖNIGL. SÄCHSISCHES METEOROLOGISCHES INSTITUT.—Jahrbuch, 1888.

CHRISTIANIA, EDITING COMMITTEE NORWEGIAN NORTH ATLANTIC EXPEDITION 1876-1878.—Zoology. Actinida. By D. C. Danielssen.

CHRISTIANIA, NORSKE METEOROLOGISKE INSTITUT. - Jahrbuch, 1888.

COPENHAGEN, DANSKE METEOROLOGISKE INSTITUT.—Bulletin Météorologique du Nord, Dec. 1889 to Nov. 1890.—Meteorologisk Aarbog, 1885, Pt. 2.

CORDOBA, ACADEMIA NACIONAL DE CIENCIAS.—Boletin, Tomo X. Ent. 3.

CORDOBA, OFICINA METEOROLOGICA ARGENTINA.—Anales, Tomo VII.

CRACOW, K. K. STERNWARTE.—Meteorologische Beobachtungen, Nov. 1889 to Aug. 1890.

CROYDON, MICROSCOPICAL AND NATURAL HISTORY CLUB.—Daily Rainfall in the Croydon District, Dec. 1889 to Nov. 1890.—Proceedings and Transactions, Feb. 1888 to Jan. 1889.—Report of the Meteorological Sub-Committee for 1889.

DORPAT, OBSERVATORIUM.—Fortsetzung der neuen Untersuchungen über die Bessel'sche Formel und deren Verwendung in der Meteorologie. Von Dr. K. Weihrauch.—Meteorologische Beobachtungen, 1881-3 and 1889.

DUBLIN, GENERAL REGISTER OFFICE.—Annual Report of the Registrar-General (Ireland) 1889.—Weekly Returns of Births and Deaths, Vol. XXVI. No. 52 to Vol. XXVII. No. 51.

DUBLIN, ROYAL DUBLIN SOCIETY.—Scientific Proceedings, Vol. VI. New Series, Pts. 7-9.

DUBLIN, ROYAL IRISH ACADEMY.—"Cunningham Memoirs," No. 5. The Red Stars: observations and catalogue.—Proceedings. Third Series, Vol. I. Nos. 2 to 3.—Transactions, Vol. XXIX. Pts. 12 and 13.

DURBAN, NATAL HARBOUR BOARD.—Chairman's Minute and Departmental Reports for the year 1889.

EDINBURGH, FISHERY BOARD FOR SCOTLAND.—Annual Report, 1889.

EDINBURGH, GENERAL REGISTER OFFICE.—Quarterly Returns of the Births, Marriages and Deaths, registered in Scotland for the four quarters ending Sept. 30, 1890.

EDINBURGH, ROYAL SCOTTISH GEOGRAPHICAL SOCIETY.—Scottish Geographical Magazine, 1890.

EDINBURGH, ROYAL SOCIETY.—Proceedings, Vols. XV. and XVI. 1887-9.

FIUME, I. R. ACCADEMIA DI MARINA.—Meteorological Observations, Nov. 1889 to July 1890.

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STOKES, J.—Annual Report on the health of Margate for 1890. By Dr. A. W. Scatliff.
STUART, M. G.—Reports on the returns of rainfall and observations on the flowering of plants and appearances of Birds and Insects in Dorset during 1888.
STURGE, R. F.—Thirty Years Weather at Bristol.
SYMONS, G. J.—Annuaire Météorologique pour l'an XIV. de l'ère de la République Française. Par J. B. Lamarck.—Coefficienti per la temperatura e per la pressione atmosferica nel barometro registratore Richard. Di Prof. D. Ragona.—Colpo d' occhio su'i grandi fenomeni atmosferici notati alla privata stazione meteorologica in Roma negli anni 1865-7 in relazioni alle burrasche. Da C. Scarpellini.—De l'accord entre les indications des couleurs dans la scintillation des étoiles et les variations atmosphériques. Par Ch. Montigny.—Die Temperatur-Verhältnisse der Jahre 1848-63, an den Stationen des österreichischen Beobachtungs-netzes. Von Dr. C. Jelinek.—Die Witterungsverhältnisse von Berlin. Von. H. W. Dove.—Essai sur l'Electricité atmospherique. Par M. L'Abbé Hervieu.—Études climatologiques sur le département de la Haute Savoie. Par P. M. Vaullet.—Étude sur les phénomènes, l'aménagement et la législation des eaux au point de vue des inondations. Par A. Monestier-Savignat.—Géographie Physique de la Mer Noire de l'intérieur de l'Afrique et de la Méditerranée. Par A. Dureau-de-Lamalle.—Histoire de l'eau. Par E. Bouant.—Il Congresso Internazionale

dei Meteorologisti riunito a Vienna dal 2 al 16 Septembre 1873. Relazione del P. F. Denza.—Instructions météorologiques et tables usuelles. Par M. E. Renou.—Le baromètre appliqué à la prévision du temps en France. Par J. R. Plumadon.—Leçons de Cosmologie adressées à Monsieur le Verrier.—Les Inondations. Par A. Landrin.—Les phénomènes de l'atmosphère. Par F. Zurcher.—Lithologie atmosphérique. Par J. Izarn.—Mémoire sur les anémomètres à indications continues établis près Cherbourg.—Note sur un anémomètre totalisateur à compteur électrique. Par M. Le Général Morin.—Nouveau baromètre enregistreur à mercure. Par A. Redier.—On barometric oscillations during thunderstorms, and on the brontometer.—Premières Notions de Météorologie et de Physique du Globe. Par M. F. Hément.—Pressione atmosferica ridotta al medio livello del mare in Modena. Di Prof. D. Ragona.—Report on the Meteorology of Toronto. By Lieut. Col. E. Sabine, F.R.S.—Results of the monthly observations of Magnetic Dip, Horizontal Force, and Declination, made at the Kew Observatory, April 1869 to March 1875.—Résumé Météorologique de l'année 1866 pour Genève et le Grand St. Bernard. Par E. Plantamour.—Riassunto dell' osservazioni meteoriche eseguite nelle Stazioni presso alle Alpi Italiane nell' anno 1872-73. Del P. F. Denza.—Sur la distribution de la nébulosité moyenne à la surface du globe. Par M. L. Teisserenc de Bort.—Symons's British Rainfall, 1889.—Symons's Monthly Meteorological Magazine, 1890.—Table of the corrections for reducing observations of the barometer to 32° Fahrenheit. By J. Glaisher, F.R.S.—Tafeln zur Reduction der in Millimetern abgelesenen Barometerstände auf die Normal-Temperatur von 0° Celsius. Von J. J. Pohl und J. Schabus.—The Physical System of the Universe. By S. B. J. Skertchly.—Torrents, fleuves, et canaux de la France. Par H. Blerzy.—Traittez des baromètres, thermomètres, et notiomtères ou hygromètres. Par M. Dxxx.

Taylor and Francis, Messrs.—Taylor's Calendar of the Meetings of the Scientific Bodies of London, for 1890-91.

Taylor, Dr. J. C.—Meteorological Observations at Las Palmas, Grand Canary, Oct. to Dec. 1888; Jan. 1889 to June, Sept. and Oct. 1890.

Tenison, E. H R.—Meteorological Observations made at Bexhill-on-Sea, Dec. 1888 to Nov. 1890. (MS.)

Tomlinson, S.—Bombay Waterworks. Report on Pawai project.

Tripe, Dr. J. W.—Winds, with some remarks on their sanitary effects.

Tyrer, R.—Rainfall in the County of Gloucester, Jan. to Nov.—The Meteorology of Cheltenham, 1889.

Veevers, R.—A Cruise in the Mediterranean.

Velschow, F. A.—On the Cause of Trade Winds.

Ventosa, V.—Método para determinar la direccíón del viento por les ondulaciones del borde de los astros.

Walker, T.—Meteorological Observations made at Addington Hills, Dec. 1889, Feb. and Apr. to Nov. 1890.

Watson, Rev. J.—Meteorological Observations made at Nuneaton, July 1890.

Wild, H.—Neuer Anemograph und Anemoscop.—Ombrograph und Atmograph.

Williams, Dr. C. T.—Photograph of the Tower of Winds, Athens.

Woeikof, Dr. A.—Voyage aux salines d'Iletzk et au pays voisin.

Wood, B. T.—Traces from Richard Barograph at Conyngham Hall, Knaresborough, Yorks, 1879.

APPENDIX VII.

REPORTS OF OBSERVATORIES, &c.

The Meteorological Office.—Lieut.-Gen. R. Strachey, R.E., C.S.I., F.R.S., Chairman of Council; Robert H. Scott, M.A., F.R.S., Secretary; Nav.-Lieut. C. W. Baillie, F.R.A.S., Marine Superintendent.

Marine Meteorology.—*Current Charts for all Oceans.*—The extraction of data for this work has been continued. The number of Remark Books which have been consulted during the year 1890 has been 5,600, covering the interval from 1862-1885.

The Meteorology of the Red Sea, and also of Cape Guardafui.—The charts for Cape Guardafui are complete. The work is in the hands of the printer and will appear shortly. The Red Sea charts are still under treatment, but it is expected that they will ere long be passed on to the engraver.

The Aden Cyclone Charts.—These have now been engraved. The only supplemental matters now required in addition, are the remarks to accompany the charts.

The Cyclone Tracks of the South Indian Ocean.—This work is now issued.

The Meteorology of the South Sea.—This has made rapid progress during the year. The whole of the material contained in the office logs has already been dealt with, and a commencement is being made with the logs of H.M. Ships obtained from the Record office. The region under discussion is the track from the Cape of Good Hope to New Zealand.

WEATHER TELEGRAPHY.—This department of the office shows no change. The *Weekly Weather Report*, with its monthly supplements, has been brought up to date, and the inspection of the Fishery barometers was completed in the course of last summer.

LAND METEOROLOGY OF THE BRITISH ISLES.—Parts II. and III. of the *Quarterly Weather Report* for 1880 have appeared, and Part IV. will shortly come out. With the issue of this part the series of *Quarterly Weather Reports*, accompanied by copper-plate reproductions of the various continuous curves furnished by the seven self-recording observatories, comes to an end.

The further issue of *Hourly Readings* has been discontinued, and in its stead it is intended to publish in future hourly means of the different elements for five-day periods, and also for each month, and for the year. The volume for 1887, which will commence the series, is in the press and will shortly be published. A discussion of the mean results obtained from the Harmonic analysis of the pressure and temperature observations made at Greenwich for 20 years, and at the observatories of the Meteorological Council for 12 years, is also passing through the press and is nearly ready for issue.

The volume of *Observations from Stations of the Second Order* for 1886 has appeared, and that for 1887 is more than half printed.

The observations made at Sanchez, Samanà Bay, St. Domingo, by the late Dr. W. Reid, have now been published.

In addition, the Registrar General for Ireland has been supplied with returns from 11 stations for his Quarterly Reports.—*February* 1891.

ROYAL OBSERVATORY, GREENWICH.—W. H. M. Christie, M.A., F.R.S., Astronomer Royal; Departmental Superintendent, William Ellis, F.R.A.S.; Assistant, William C. Nash. No change calling for any special remark has been made in the routine of observations or reductions during the year 1890.

The meteorological photographic records are maintained as in former years: these include records of the barometer, of the dry and wet bulb thermometers, and of Thomson's electrometer. The Osler anemometer, giving continuous record of the direction and pressure of the wind and of the amount of rainfall, and the Robinson anemometer giving record of velocity, are also in good order. Since the summer of the year 1889, the old Robinson anemometer by Negretti and Zambra has been mounted by the side of the larger instrument by Browning, which has been in use since the year 1866, and corresponding readings of the two instruments have been taken daily for the purpose of comparison of their records.

The observations of the temperature of the air by thermometers placed in a Stevenson screen are still maintained, as well as observations of thermometers placed on the roof of the Magnet House 20 feet above the ground.

The volume for the year 1888 has been recently published, and the printing of that for 1889 is nearly completed.

The collection and reduction on one system of the results of the magnetic photographs from 1865 to 1882 in a manner corresponding to that adopted in 1883 and following years, has made considerable progress. When completed, it is proposed to undertake the preparation of a more complete system of meteorological averages than at present exists, the material that has accumulated since the establishment of the Magnetical and Meteorological Observatory in the year 1841 being used to give daily means of various meteorological elements on an average of 50 years' observations.—*February 2nd*, 1891.

ROYAL OBSERVATORY, EDINBURGH.—Ralph Copeland, Ph.D., F.R.A.S., Astronomer Royal for Scotland.

The meteorological work at the Edinburgh Royal Observatory during the past year has consisted of the reduction of the observations taken at 55 stations of

the Scottish Meteorological Society, and the preparation of weather returns for the Registrar General for Scotland. These comprise a monthly summary for eight of the chief towns in the country, and a quarterly summary for the whole of the stations. Daily readings are taken at the observatory at 1 p.m., and the earth thermometers are noted with extreme care every Monday at noon. At the close of the year a new rain gauge was started 12 inches above the ground-level at the request of Mr. Symons. The rain caught by it promises to differ materially from the record given by the old gauge on the roof, which is higher by 28 feet.—*February 9th*, 1891.

THE KEW OBSERVATORY OF THE ROYAL SOCIETY, RICHMOND, SURREY.—G. M. Whipple, B.Sc., F.R.A.S., Superintendent.

The several self-recording instruments for the continuous registration respectively of atmospheric pressure, temperature, and humidity, wind (direction and velocity), bright sunshine, and rain have been maintained in regular operation throughout the year.

The standard eye observations for the control of the automatic records have been duly registered, together with the daily observations in connection with the U.S. Signal Service synchronous system.

The tabulations of the meteorological traces have been regularly made, and these, as well as copies of the eye observations, with notes of weather, cloud, and sunshine, have been transmitted to the Meteorological Office.

Tables of the monthly values of the rainfall and temperature have been regularly sent to the Meteorological Sub-Committee of the Croydon Microscopical and Natural History Club for publication in their *Proceedings*. Detailed information of all thunderstorms observed in the neighbourhood during the year has been forwarded to the Royal Meteorological Society soon after their occurrence.

The electrograph has been in constant action throughout the year, and comparisons with the portable electrometer have been made from time to time.

The supply of the chart exhibiting copies of the daily traces of the self-recording meteorological instruments at the Observatory ceased by instructions from the *Times* office on March last, after continuous publication for 14 years.

The fog gauge set up on the north side of the Observatory in 1884 has been recently dismounted, as it was not found possible to measure the intensity of this phenomenon by its means.

At the request of the Meteorological Council, the barograph and thermograph which have been stored at the Observatory since their return from the Armagh Observatory in 1886, have been thoroughly re-fitted, and, after a short experimental trial at the Observatory, re-packed and forwarded to the new Observatory at Fort William for use at the low-level station worked in conjunction with the Observatory erected on the summit of Ben Nevis. In June last, on receipt of information from Mr. Omond, the superintendent of the Ben Nevis Observatory, that the new building was ready for the reception of the instruments, Mr. T. W. Baker proceeded to Fort William and set them up and put them in proper adjustment. Having done this, and instructed Mr. Omond in their manipulation and the attendant photographic operations, he returned to Kew, leaving the establishment in good working order in July. Owing to difficulties attendant on the regular supply of gas, it was found advisable to adapt the burners for the consumption of mineral oil, on the pattern of those employed at the Observatory at Valencia Island, Ireland, for the last 22 years, with great success.

During the past summer 225 series of observations of the sun's actinic power have been made with Violle's actinometer, described in the last Annual Report, upon the plan arranged by General Strachey and Mr. Blanford.

The electrical anemograph, after working on the staging erected on the roof, 14 feet to the north of the Beckley instrument, and recording by means of a battery composed of eighteen Fuller's cells, was dismounted on July 22, and packed for storage. During the period it was at work, the traces were forwarded weekly to the Meteorological Office.

At the request of the Meteorological Office, various specimens of lubricating oils have been applied to the gearing of the anemograph with the view of determining the best for use under the varying conditions to which it is exposed.

At the suggestion of General Strachey, Chairman of the Meteorological Council, a new departure has been made in the photography of clouds during the

past year, with the view of simplifying the operations of determining the height and velocity of their movement. Both cameras have been rigidly fixed on their stands, with the axes of their lenses pointed directly to the zenith, and photographs are now taken simultaneously of the area of the sky surrounding the zenith within a circle of a radius of about 15°. A frame has been constructed in which these photographs are superposed one on the other, so that the two pictures shall appear to coincide, and a simple measurement of the distance between the images of the zenith points, which are marked by intersecting lines, gives a means of readily determining the height of the cloud above the surface of the ground. A second measurement made in like manner of the displacement of the zeniths in a second pair of photographs taken after a given interval of time serves to show the rate of travel of the cloud and the direction in which it is moving at the instant of observation. Twenty groups of clouds, giving heights extending from 1¼ miles to 8 miles, and rates of motion from 5 miles to 64 miles per hour, have been photographed and measured in this manner during the past summer. A light framework, 12 feet in height, has been constructed, which is occasionally erected above each of the cameras in order to verify the position of their zenith points and the orientation of the cross lines on the photographic plates.

The Committee having considered the desirability of possessing some thermometers which had been accurately compared with the hydrogen thermometer of the Conservatoire des Poids et Mesures, at Paris, instructed Mr. Whipple to convey to the director of that office the set of three closely graduated mercurial thermometers, whose errors were investigated in 1879, by Professors T. E. Thorpe and Rücker (see *British Association Report*, 1881, p. 540), and also an alcohol thermometer graduated at Kew for the special purpose of the comparison, its scale extending from —100° to +90° Fahr. The examination of these thermometers has now been completed, and M. Benoit has sent his report upon them to Kew Observatory.

In addition to the usual instruments submitted for verification, the Committee have been called upon for special examination and reports upon the following articles: the Admiralty, for a Gun Director Telescope, and new pattern Officer's Telescope; the War Office for a barometer supplied to the Netley Hospital; and the makers for a new Watkin's Clinometer, and Watkin's Aneroid with open scales: as well as various instruments for the Anglo-German Boundary Commission on the Gold Coast.

The Chairman of the Committee, with a view of making the public more conversant with the systems of verification and rating in use at the Observatory, prepared in the early part of the year a pamphlet entitled "Tests and Certificates of the Kew Observatory." Of these 1,000 copies were printed, of which 200 have been distributed to the principal opticians and instrument makers.

The necessary apparatus to enable the examination of photographic lenses for cameras to be prosecuted at the Observatory, with the view of granting certificates to the owners or purchasers of such articles, has been prepared, and it is in contemplation to adopt two such schemes of examination of lenses, one, a comparatively rough or cursory trial which will enable a person to form a general idea of the capabilities of a lens, whilst the more lengthy and careful trial, for which a higher fee will be charged, will give full particulars as to the various qualities an acquaintance with which is necessary to possess a full knowledge of the instrument. Captain Abney and other gentlemen have rendered the Committee much assistance in the practical arrangement of the details of this lens testing.—*January 20th*, 1891.

Radcliffe Observatory, Oxford.—E. J. Stone, M.A., F.R.S., Radcliffe Observer.

The following is a report on the meteorological work of this Observatory for the year 1890:—

The eye-observations have been made on the plan stated in the report for 1889. But, with respect to the continuous registration of the meteorological instruments, it has been found much more convenient to adhere to the plan on which the meteorological reductions have been made in previous years; and, to begin and end the day at noon.

The self-registering instruments have worked satisfactorily throughout the year; and the argentic gelatino-bromide paper, brought into use in February 1890, has given satisfaction.

Weather Reports have been sent, as in previous years, daily (by telegram) to the Meteorological Office; bi-monthly to the United States Signal Office; monthly to the Registrar-General and local newspapers; and yearly to Symons' *British Rainfall;* and to others by request.

The eye-observations are reduced to date. The *Meteorological Results* for 1886 have been printed, and were distributed last November. The *Results* for 1887 are under discussion.

Dr. Haldane and Mr. M. S. Pembrey have completed their experiments, at the Observatory, on the moisture in the air, and their results have been printed in the *Philosophical Magazine* for 1890, page 306.

The mean temperature of the air for last December was 28°·9, or 10°·6 below the average of the last 35 years' observations. The mean temperature for the day on December 22nd, was 10°·8, being 28°·0 below the average temperature for that day: the lowest reading for the past winter, 8°·0, was also recorded on that day. The total rainfall for the year 1890 was only 18·400 ins., which is 7·994 ins. below the average of the last 39 years' observations, and smaller quantities have fallen only in the years 1854, 1864, and 1870 during this period. The total amount of bright sunshine for the year was 1,411 hours. Only 5 hours were recorded during December.—*February 19th*, 1891.

Note on a peculiar development of "Cirrus" Cloud observed in Southern Switzerland.

By ROBERT H. SCOTT, M.A., F.R.S.

[Received December 2nd, 1890. Read January 21st, 1891.]

On Friday, August 22nd, 1890, I was at San Carlo, in the Val Bavona, a tributary of the Val Maggia, in the Canton Ticino. San Carlo lies on the northern side of the Basodino, a well known peak in that district.

The weather had been exceedingly bright and warm for several days. At about 2 p.m. I noticed "cirrus" coming from the north-west, over the St. Gothard district, which lay nearly due north of my position. The cirrus appeared to rise from a distinct bank of stratified cloud of small extent, not dense enough even to deserve the name of "stratus." From this depended a decided tail, or funnel-shaped cloud. This precisely resembled the cloud funnels which accompany whirlwinds, or so-called tornadoes.

I at once remarked to my companion, "that means a break-up of our hot weather," and sure enough, on the 24th, two days later, a terrific thunderstorm burst over the district, and lasted in those valleys for about 24 hours. This electrical disturbance was accompanied by very serious hailstorms, which devastated the agricultural products, such as grapes and maize, in some parishes. At Bignasco, where I was staying, the fall on the 24th was 93mm (3·66 inches).

The succeeding week was very wet, the fall being such as to raise the level of the Lago Maggiore by about six feet. The wet weather terminated on the 31st, with another 24 hour thunderstorm, also accompanied by local tornadoes and hail. Hailstones were reported at Monte Generoso, of which six

weighed a kilogramme. At all events a hailstone weighing 5 oz. is a formidable missile. Enormous damage was done near Como.

The appearance of a possible whirlwind cloud, at the level of cirrus, followed by electrical manifestations of extraordinary violence and continuance, is my excuse for submitting this note to the Society.

I regret not having made a sketch, so as to record, however roughly, the phenomenon.

DISCUSSION.

Rev. W. Clement Ley wrote:—"Was any spiral or whirling motion discernible in the funnel shaped cloud tail?

"On the reply to this query a good deal depends, both of the value of the Note, and of that of my discussion following its lines.

"'Tails,' of what I have termed 'pseudo-cirrus pendulus' can often be seen (at the close of fine summer weather) depending from a patch of rather cumuliform ice-cloud, perpendicular when the movements of the atmosphere in the neighbourhood of the cloud are uniform; inclined at various angles to the earth's surface whenever (as is most commonly the case) when the upper surface of the cloud is moving with a velocity or direction differing from that of the air below, where the tail of descending ice-crystals undergoes evaporation. Here spiral movements are not visible, and all questions relating to the cloud-form are very simple.

"If, on the other hand, spiral movements were observed at the cirrus altitude, this Note will ultimately involve an entirely novel departure in the dynamical theory of the movements of the atmosphere.

"'Funnel clouds' at the base of Cumulus and Cumulo-nimbus are very common indeed. To explain the formation of such clouds in the Cirrus region would be a new, and, I think, a most difficult task."

Dr. Marcet said that it was remarkable that a violent storm occurred in the Valley of Joux, near Neuchatel in Switzerland, at about the same time as the storm described by Mr. Scott. This storm was very destructive, many houses and a large number of trees being blown down.

Mr. Symons said that the latter part of August 1890 was remarkable for the frequency and severity of the tornadoes or whirlwinds which prevailed. Among the most violent were the following:—

On the night of August 15th, a storm in the vicinity of Carcassone, in the Department of Aude, in the South of France, in which the damage, chiefly by hail, was found to have exceeded 25,000,000 francs (one million sterling).

On the night of the 18th, two storms, in each of which great wreckage was produced by wind. The first was near Miremont in the Department of Dordogne in the south-west of France; and the other passed south-west of Paris, from Dreux in Eure et Loire, to near Mantes, in Seine et Oise. The ruins at Dreux (where the path of the whirlwind went right across the town) had been visited and photographed by M. Teisserenc de Bort and by Mr. Rotch.

On the night of the 19th a similar storm, with excessive wind and hail, visited St. Claude in the Jura, and crossed the frontier into the Canton Vaud, Switzerland, wrecking churches, houses, and vineyards.

On the 25th a destructive storm passed over Citta di Castello (Perugia), about 100 miles north of Rome, which overthrew four churches, did great damage to house roofs, and injured many persons. At Pistuno, in the same neighbourhood, a house fell and buried several persons, and the adjacent Commune of Citerna was devastated.

Mr. Whipple said that he was much interested in this account of cirrus cloud formation, as he had been keeping a particular watch for the past year or so in order to secure good photographs of cirrus clouds. He called the attention of the Fellows to the desirability of carrying a small photographic camera, such as the "Kodak," with them when travelling, as they would then be prepared to take photographs of clouds or other objects possessing meteorological interest which they might happen to meet with. He had seen, a few hours previously, at the Royal Astronomical Society, an engraving of ball lightning observed in

the streets of Toulouse, and thought that an observer who might by chance obtain a photograph of this phenomenon would be indeed a most fortunate individual, and amply repaid for his trouble in carrying the apparatus.

Mr. BRUCE remarked that shortly after the occurrence of the storm described by Mr. Scott, he travelled by railway from Basle to Rheims, and along the whole French route he saw evidence of the violence of the storm.

Mr. SCOTT stated that as far as he was able to fix the level of the cloud he observed, it appeared to be at the level of cirrus. At all events, it must have been above 12,000 feet high, for it was clearly higher than the St. Gothard peaks, which reach about to the level of 10,000 feet. He begged to append a copy of a letter on the subject of his paper which he had received from Dr. Hann.

Extract from a letter from Dr. JULIUS HANN, dated Nov. 20, 1890, to Mr. Scott:—"Your cirrus observation is very interesting. I myself have never seen anything of the kind, or, at least, my attention has not been specially attracted by it. Possibly, at the time of your observation, there existed a sort of unstable equilibrium between the upper and lower strata of the atmosphere. I think that I have somewhere or other drawn attention to the circumstance that not very uncommonly on the south side of the Alps the lower warm strata on the lee side (*Wind Schütze*) of the Alps are covered at a great height by colder currents. It would take some time before the reaction between the two brings about a condition of more stable equilibrium. Your observation of a sort of funnel cloud (*Trombe*) appearing at the height of cirrus might easily fall in with this idea. The Alps would certainly, up to the level of 3,000 metres, delay the mixture of these currents, so that the upper currents must move at the level of 5,000 metres and upwards. Many phenomena at the commencement of thunderstorms on the Plain of Lombardy, especially as to their frequent accompaniment by hailstorms, might be easily explained on this idea.

"At all events, you should print your Note, if possible with a simple sketch, as it is new, and deserves to be generally known."

SOME REMARKS ON DEW.

Being Notes on Observations which were made to discover whether Dew is all deposited from the Air, or if some also comes from the Earth and Plants, and also what quantity is formed during the Year.

BY COLONEL W. F. BADGLEY, F.R.Met.Soc.

[Received November 15th, 1890.—Read January 21st, 1891.]

I WAS first induced to make these inquiries by seeing that my camp boxes in India, after being on the ground at night, were wet underneath, and by noticing that the arrangement of the drops of dew on the edges and points of the leaves of corn and other plants was such as could not have been due to the deposit of dew from the air. I should have followed up my ideas much earlier but for the difficulty of deciding on a method of working them out. I had not seen Wells' book on *Dew*, and the only meteorological work I had read hardly mentioned dew at all. It was not till the beginning of 1888 that chance led me to begin observations. At that time I received a box with a thin zinc lining; I cut the zinc into plates, exposed them, and found that owing to their thinness and dullness through oxidation they condensed the dew perfectly, and that my chief difficulty was ended.

I made the first set of observations in India in 1888, while in camp on the Pulney Hill plateau, in latitude 8°30′ N., and at heights varying from 7,500

to 4,500 feet above the sea. They were few, as the camp moved every day, and there were not many suitable places with short grass and free exposure to the sky to be found, and also because the wind, which was from the North-east and very dry, blew strongly for some time and dried up the dew as it was deposited. During the best weather this wind would often set in towards morning after a calm night, so I always covered the plates over at 4 p.m. and examined them at sunrise.

The second series of observations I made in 1889-90, at Kyrewood House, near Tenbury, in Worcestershire, at a height of about 400 feet above the sea, the locality being a tennis lawn between a garden and an orchard, with a pretty fair exposure to the sky and grass kept short by a machine.

I used two zinc plates about 8½ inches in diameter and dull with oxidation These I laid on the grass about sunset and took up about sunrise. One side of each plate I dried, and weighed the plate with the dew on the other side. The dew on the grass, which had been covered by one of the plates I took up with blotting paper, and added its weight to that of the dew on the underside of the plate. I made the measurement of the dew by weights representing drops, 300 of which were made to go to an ounce avoirdupois, as I found that 10,000 such drops would cover my plate (with an area of nearly 58 square inches) just 1 inch deep, and that therefore, in recording, all that would be needed to convert a drop into its depth in decimals of an inch, would be to apply a decimal point and three ciphers.

In the English experiments I exposed a third plate on a tripod at 5 feet from the ground. The quantities of dew on the two sides of this plate were usually equal or nearly so, but occasionally there was a decided difference, and more often when this happened the greater quantity was on the lower side of the plate. In the record sent to the Society[1] I have entered the half of the whole amount of the dew on both sides, except when it rained, when I give the quantity on the underside.

At the end of the twelve months' record I have added a table giving some experiments made to find what quantity of dew is exhaled by plants. There are not many of these, as I could make none when the leaves were wet in the evening with rain, and I rejected those made on nights when it rained, as some of the rain might have trickled into the tube. This article, in which the exhalation was collected, is a thin zinc bottle about 10 inches long by 3½ in diameter at its widest part. I set it an inch or more above the ground, according to the plant examined; some of the leaves being inside, I closed the mouth with a crumpled leaf, and in the morning measured the area of the leaves and weighed the water in the bottle, and from these have calculated the depth of dew.

In the records of observations with zinc plates, column 1 gives the date of the day following the night of observation. Columns 2 and 3 give the quantities of dew collected on the upper and undersides of plates exposed on the grass. Rain or wet fog during the night is shown by a dark line in

[1] These observations are preserved in the office of the Society.—Ed.

column 2. Column 4 gives the dew collected on one side of a plate supported at 5 feet from the ground. Columns 5 and 6 give the minimum temperature for the night of observation and the maximum for the date. Column 7 gives the humidity of the evening before the night of observation. And the remaining columns give roughly the direction and force of the wind and the aspect of the sky.

A total of the dew collected on the plates exposed on the grass is given at the end of each month, and to this has been added what, by calculation, ought to have been found on the upper side of the plate on nights when it rained, and this increased total is taken as the dew for the month.

The following are the conclusions which I deduce from the observations, and my reasons for them :—

I. That the earth always exhales water vapour by night, and probably a greater quantity by day.

The record of observations shows that on many nights during the twelve months, a considerable quantity of water vapour rose from the earth and was condensed as dew on the under-surface of the plates laid on the grass. It is apparent, also, that the amount of dew condensed from this vapour depended on the favourableness of the weather. On nights with a clear sky and a gentle wind the quantity was always large, while the more unfavourable to radiation and the more windy the night, the less dew there was. Therefore, presumably, had there been no wind, and had the plates being cooled equally by radiation every night, the earth vapour would have been condensed equally on every night. Also, as Wells in his treatise on *Dew* has shown, that in favourable weather dew is formed all through the night, and as it appears from my observations that much of the dew comes from the water vapour given off by the earth, it follows that vapour issues from the ground continuously during the night. If it do so throughout the night, it may be concluded that it continues to do so during the day, and that the earth always exhales water vapour.

As to the second part of my theorem, that the earth exhales a greater quantity of water vapour by day than by night, I am undertaking some experiments to test the quantities, and intend to continue them for twelve months.

II. That the quantity of water vapour given off by the earth is always considerable, and that any variation in the quantity is mainly due (in England) to the season of the year.

I have taken the average quantity of dew collected on the underside of the grass plate on those nights in each month which were most favourable to radiation or were frosty, and dividing these by the number of hours during which the plates were exposed, I find that the quantities condensed, in decimals of an inch per hour, are as follows :—

November	...	·00043	March ...	...	·00043
December	...	·00043	April ...	...	·00050
January	...	·00037	May ...	...	·00055
February	...	·00034	June ...	...	·00072

July	·00061	September ...	·00053
August ...	·00061	October ...	·00049

That is to say, the exhalation in summer is twice as much as in winter. The mean of the above figures is ·000501, which is the average quantity of dew from the earth vapour in an hour at night, and if the earth gives off as much vapour during the day as during the night, then during the past twelve months the earth has exhaled vapour sufficient to produce more than a hundredth of an inch of water daily, or nearly 4½ inches in the year, which is over a sixth of the rainfall in this county (Worcestershire); as the weather during this time has been more dull and cold and less rainy than usual, this amount of moisture exhaled is below the yearly average.

III. That the greater part of the dew comes from the earth vapour.

This is plain enough from an inspection of the record. During the twelve months 1·2040 inches of dew were collected on the underside of the grass plate, and ·3677 inches on one side of the plate raised 5 feet from the ground. That is, the dew from the earth vapour exceeded that from the air vapour in the proportion of more than 3 to 1.

On particular nights, when everything is favourable, the dew condensed from the air may exceed that from the earth vapour, and there are seven instances of this in the record in the months of September and October; but taking the year through, the quantity supplied by the earth is, as shown above, very much more than that from the air, and I am surprised that so acute an observer as Wells should have missed this. It was no doubt owing to his observing on fine nights only, for his cotton wool method was not suited to any other weather. It will be noticed that on the seven nights referred to, and as a general rule on every night on which dew was found on the raised plate, the quantity on this plate has exceeded that on the upper side of the grass plate, and that the wind was calm or very light. Also, that in most cases where dew was found on the upper side of the grass plate and none on the raised plate, there had been moderate or strong wind. The wind, in fact, moving more slowly along the ground than at 5 feet above it, was able to get at the raised plate more easily, and in the one case to dew it, and in the other case to dry it, more thoroughly than the plate on the grass.

I think it probable that on favourable nights the greater part of the vapour from the earth is condensed before it passes the surface of the grass, and that whatever dew is found on the upper surface of the grass plate on such nights is for the most part moisture brought by the air from a distance.

IV. That plants exhale water vapour, and do not exude moisture.

At the end of the record of observations with zinc plates I have given a table showing the results of some experiments made with a zinc bottle, in which I enclosed sprays of different plants on nights more or less favourable to radiation. In this table I have given, as in the previous ones, the aspect of the sky, but omitted wind, temperature and humidity, as not necessary to the inquiry.

The bottle was set in the evening, when the plants were dry, before dew began to form, and was supported horizontally, at whatever height was re-

cessary, with some of the plant experimented on inside. The mouth was closed lightly with a crumpled leaf and the results examined in the morning.

I found that some plants gave better results than others, notably oats, some plants of which had sprung up in the garden from seed brought with the manure, and which I had saved from the gardener's clutches. Grass disappointed me; but its situation in a meadow, where the bottle was somewhat sheltered by the surrounding grass, may have had to do with the small results.

I was quite satisfied that the water collected in the bottle came from the plant, but in case an objection might be made that it came from the air in the bottle and not from the plant, I tried the experiment, on a clear night, of setting out the empty bottle, closed as usual with crumpled leaves, and in the morning found no result that would affect my balance. The experiments recorded were rough, but they were on a sufficiently large scale to produce easily measurable results, and no trial was made when the plants were wet from previous rain, nor was a trial recorded if rain fell in the night for fear some drops might have trickled into the bottle. Mr. Aitken's observations, however, sufficiently prove that plants produce water in quantity.

On examining the bottle in the morning I found that moisture was collected on its inner surface—sometimes as much as a teaspoon full—and that the plant was itself nearly dry. No other explanation of these circumstances occurs to me except that the moisture found in the bottle was given off as vapour by the plant, and was condensed from the air, with which it then mixed, by the cold sides of the bottle.

I believe that plants give off aqueous vapour in the same way that they give off carbonic acid and other gases, and that the drops seen on the edges of leaves on fine nights are so formed because of the immediate condensation of the vapour on its issue from the pores of the plant, and if examined would be found to be pure water—dew in fact—and in no manner mixed with the juices of the plant, which would certainly be the case were it an exuded fluid.

I may remark that where I have mentioned the earth and the vapour from it in the above notes, I have included the grass covering and the vapour from this grass. It would have been uselessly confusing to have made a distinction between the soil and its covering before this, but I will now detail an experiment made to try to find what part of the dew on the underside of the plate on the grass might be supposed to come from the earth vapour and what part from the plant vapour. I cut the grass and weeds from a measured piece of the lawn, and took the area of all the green leaves. I found that the 58 square inches of soil covered by my grass plate bore upon it 142 square inches of leaf, taking both sides of the leaf into account. The average depth of dew from the vapour of plants in all my experiments is ·000465 of an inch, which, multiplied by 142, the area of the grass, and divided by 58, the area of the plate, gives ·001121 inch as the average quantity the plate would have condensed from a mixture of these plants. The average quantity of dew condensed on the underside of the grass plate on the same nights is ·004057 inch, of which, therefore, about three parts

came from the soil, and one part from the grass on it, if the grass be allowed to represent the mixed plants. So much, however, cannot be said to hold good for the whole year. These experiments were made from April to September. Probably in winter plants—even those that are evergreen—give off little water vapour, while the soil, retaining its heat unchanged at a short distance below the surface, continues its exhalation of vapour with much less change.

The total quantity of dew collected on the grass plates in the year was 1·6147 inches.

I will end my notes with a few remarks about some peculiarities that may be noticed in the daily record.

The case of November 26th and 28th is peculiar. On the first date there were 89 drops on the upper side of the grass plate, and on the second date only 5; both nights were clear and frosty, but on the first night there was a damp West wind, and on the second a dry North wind.

On December 14th there were 86 drops below the grass plate, and the sky was clear; on the 15th 12 drops only, and the sky cloudy. The minimum was 28° on both nights. Evidently the surface of the grass was warmer than the air on the second night, or the dew would have been frozen and retained on the plate, as on the first night.

On December 16th there was nothing on the grass plate, but 3 drops on the 5 foot plate. The explanation is that the radiation was sufficient to cool below dew-point the isolated plate, but not the plate in proximity to the warm earth.

On December 29th, and January 2nd and 3rd, it froze hard day and night; but the plates put out on the grass had condensed on their under-surfaces 86, 52 and 41 drops. Other cases of the same sort are March 3rd and 4th. Evidently such frosts as occur in England do not prevent the aqueous vapour of the earth from rising.

On January 31st there was nothing on the raised plate, 2 drops on the upper side of the grass plate, and nothing underneath. Probably there had been a very light rain, and the light wind had not been able to get at the plate on the ground to dry it, though it had dried the raised plate.

There were fourteen nights on which no dew was found on the grass plates; but the weather on all was very unfavourable to the formation of dew, and they therefore afford no reason for supposing that the earth did not give off vapour as usual.

I have made out nothing new from the observations for humidity.

I regret that I did not begin earlier in India, or had not further time for observations. I have given those made in the Pulney Hills merely to show how heavy the dew is in the Tropics. The place where they were taken is a hill plateau, rising abruptly to a height of a mile and a quarter above the plains, and surrounded with magnificent precipices, some of them 2,000 feet high. The top is undulating and hilly, covered with grass, with little forest but with some lovely waterfalls and hill scenery. Beside an artificial lake three miles round, a sanatarium has been established there, with a delightful

climate in summer and frosty nights in winter. The dew at times is excessive. Temperature has a great deal to do with this, the change between day and night in winter being often 45° or more. I have several times found the thermometer 28° at night, and above 75° in the day, and nearly the whole of this change occurs between sunset and eight o'clock. The feeling is like entering an ice house. I inadvertently tore up my notes on temperature after using them for my official report on work in the Pulney Hills, and so have to leave the record incomplete.

The observations show how much wind interferes with dew, and the entries of March 13th and 16th are instructive, the plates having been heavily dewed, though placed on bare ground. So also are those of February 6th and 19th March, showing that though the soil had been drying up, without rain to speak of, for a month and a half, the amount of vapour given off by it was nearly the same.

Note by the Author.—The plates were exposed on the grass, there was, therefore, no circulation of air under them. The manner in which the bottle was closed was sufficient to prevent outside moisture from being deposited inside, which was all that was required. No iron or dry wood was used. The maximum and minimum temperatures are given for every day, though the observations were not made to discuss the effects of temperature or other points sufficiently investigated long ago. A paper regarding most of the points referred to in my notes was published (I believe) by Mr. Aitken a month or more before mine was sent to the Society, and Wells' theory was therefore modified from the prior date.

DISCUSSION.

The Hon. F. A. R. Russell said that the author had omitted to state how close to the grass the plates were placed, and much would depend on the freedom of circulation of air between the plates and the ground. The experiments made by the author did not appear to establish any conclusion, for causes of error were not sufficiently guarded against, and same of the terms used were not convenient. For instance, by "exhalation" and "exudation" we may probably understand "evaporation." There were, no doubt, great differences in the manner in which dew deposited itself on different occasions, and the same might be remarked in rimy frosts. Quite recently he had observed, after one severe frost, that the rime, instead of being formed mainly on the upper surfaces of leaves, twigs, &c., was very much thicker on the under surfaces, and he could not say for certain what circumstances brought this change about, but probably owing to the atmospheric condition and fog overhead the radiation, after a fog came on, had been more intense towards the hard frozen ground than towards the sky. It is remarkable how decidedly rime usually grows on the windward side of any object, and the lightest air is sufficient to cause the fine needles to form abundantly on the side from which it blows. The author's experiment with the plant in the bottle seemed to be vitiated by the manner in which the bottle was imperfectly closed with leaves. "Exudation" was out of the question where iron and dry wood became covered with dew. However, these observations should be followed up, especially with regard to the deposition on plants, and might lead to results of some value.

Mr. Whipple thought the paper did not contribute much to our knowledge of the formation of dew.

Mr. INWARDS said that it was to be regretted that the author had not tried the experiment of placing one plate on the top of another and larger one, so as to ascertain whether any moisture was collected on the under side of the top plate, from which any moisture issuing from the soil might be supposed to be effectually cut off.

Mr. SYMONS said that he had never studied the formation of dew, but he believed the maximum amount of dew which could be collected from one night's deposition was 0·15 in. This paper raised one subject which was frequently lost sight of when the question of dew was under consideration, viz. the evaporation from the earth. This point had been carefully thought out nearly half a century since by the Rev. L. Jenyns (now Rev. L. Blomefield) in sections 219 to 227 of his *Observations in Meteorology*, which it would be well to read along with Col. Badgely's paper.

Mr. C. HARDING inquired whether Mr. Dines could give them any information concerning the experiments on the formation of dew made by his father, the late Mr. George Dines. He believed Mr. G. Dines had said that he often found much more dew deposited on the under side of a flat piece of wood raised about 4 inches above the ground than on its upper surface. It was a pity the author of this paper had ignored temperature, as the results would doubtless be affected by this factor. He considered further experiments necessary before any modification of Wells' theory could be established.

Mr. W. H. DINES said he was afraid he could not give much information concerning his father's experiments, but so far as he recollected the conclusions his father came to were that a still night was most favourable for the formation of dew, with a high temperature during the day and a low night temperature. The board referred to by Mr. Harding was used for exposing thermometers in connection with some experiments to ascertain the amount of terrestrial radiation. It was about 6 ins. from the ground. His father had found that the readings of the thermometers underneath the board were sometimes much lower than the readings of those on the top of the board.

Mr. M. JACKSON said that he had noticed that the deposition of dew was generally greater after a series of heavy rains, when the earth was thoroughly soaked, than it was in dry weather, and he therefore was inclined to think that more dew was derived from the ground than from the air above it.

Mr. MILLER said that several years ago he had conducted a series of experiments upon the amount of evaporation from various soils and plants, the results of which were embodied in an essay which was to be found in the Library of the Society. He proposed, as soon as leisure permitted, to continue these experiments further, using various films.

THE PROBLEM OF PROBABLE ERROR AS APPLIED TO METEOROLOGY.

BY THOMAS WILLIAM BACKHOUSE.

(Communicated by G. J. SYMONS, F.R.S.)

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THE average or arithmetical mean has always been accepted and used as the best rule for combining direct observations of equal precision upon *one and the same quantity*. This universal acceptance may be regarded as sufficient to justify the axiom that it gives the most probable value; for after all, as Laplace has said, the theory of probability is nothing but common sense reduced to calculation.

But what is true with regard to (for instance) measurements of some object

whose dimension is real and fixed, is not equally true as applying to measurements of different objects, the average of such measurements being an ideal quantity. A series of annual rainfalls are measurements of varying quantities, and one would expect that the ideal annual rainfall would be better expressed by the geometric mean than by the arithmetical average.

A series of numbers, of which the varying quantities for yearly rainfall are a good example, may give rise to calculations upon the likelihood of any of them recurring, or the probability of any other selected number taking place.

Arithmetically, the consideration of the probability of any quantity of rain falling is one of *differences*, that is, the chance of the occurrence of a given quantity exceeding the average would be the same as that of one less than the average by the same difference; or the chance of *twice* the yearly average rainfall would be the same as *no rain at all* in a year! But the consideration of any *proportions* of the average is the treating of that average geometrically; that is, the chance of *twice* the yearly average rainfall occurring is the same as that of *half* that quantity; the chance of three-halves the average the same as two-thirds; that of five-fourths the same as four-fifths the average; and so on.

When the *frequency* of recurrence is required, then the statement of the probable error of the average or mean, or the probable error of the components of the average or mean, must be set forth; the probable error being calculated in the ordinary way by the method of least squares.

Though the geometrical mean of itself may not, and where the components are within somewhat narrow limits will not, be of much greater precision than the arithmetical average; yet with the necessary geometric treatment of the deviations its value is enhanced and emphasised.

As illustrating the justness of the theory for the treatment of deviations geometrically, it may be cited that in *British Rainfall* for 1881, p. 18, and 1883, p. 29, there occur the statements derived from percentage calculations of a long series of yearly rainfalls at several places, that marked excesses above the average are more frequent than deficiencies—as they should be geometrically; and that the excess in the wettest year is one-and-a-half times the average, and the defect in the driest year is not more than 65 per cent. of the average—which is the same as the geometrical statement that three-halves is equally likely with two-thirds the average.

I am therefore surprised at not having seen the views of Galton on "The Geometric Mean, in Vital and Social Statistics," and their enlargement by MacAlister entitled "The Law of the Geometric Mean," both of which papers appear in the *Proceedings of the Royal Society*, Vol. XXIX. pp. 365-376, applied to meteorological statistics, since these gentlemen pointed out the mode and importance of their application. I have only noticed one such attempt to adapt them, and that in a case to which the principles were not really applicable, so that it was, of course, unsuccessful.

In order to show whether the application of these views is justified, there follow here some calculations on 90 years' rainfall at Sunderland (*i.e.* since I

commenced to observe it). Table I is thus explained: Columns (1) and (2), (5) and (6) contain the annual rainfall from 1860 to 1889 in order of time and order of amount respectively; column (3), the logarithms of the yearly quantities; at the bottom of columns (2) and (3) occur the arithmetical average, probable error, and "quartile" of the figures in these columns, for the whole 30, for the first 15, and for the second 15 years; column (4) contains the natural numbers corresponding to the averages, probable errors and "quartiles" of the logarithms in column (3). Columns (7) and (8) contain the deviation of each yearly quantity and of its logarithm from their arithmetical averages for the 30 years.

The "quartile" (as Dr. MacAlister calls it, but known in some text books as "probable error of one observation") has such a value that the number of deviations from the average greater than it is the same as the number less than it; or, the chances are even that a deviation taken at random will be greater or less than the "quartile."

In accordance with the principle of the geometric mean the results from the logarithms are theoretically the more correct, though their collation with those derived from the ordinary average shows that in the present investigation it makes but little difference which is used.

Table II is as follows: Column (1) contains coefficients (in half units) for a suitable range; column (2), the values of the percentage probability integral (see Table II of Merriman's *Text Book of Least Squares*, p. 187); column (3), this probability integral for 30 years; columns (4) and (5), the number of times the quartile multiplied by coefficient in column (1) occur in the 30 years.

When either the quartile or probable error,[1] together with the number of observations, is given, we can readily find out by the aid of tables the proportionate number of occasions that any particular amount of rain is likely to occur on. For example, taking the results derived from the logarithms:— Below four-fifths, or above five-fourths the mean, *once in 11 years.* For the greatest deviation that has occurred in the 30 years, viz. that whose difference of logarithm from the logarithm of the geometric mean is 0·1530 (*i.e.* representing a rainfall of 36·86 inches or more, or 18·22 inches or less), *once in about 160 years.* Below half, or above twice the average, *once in about 400,000 years.*

As shown by Table II, the agreement of observed and calculated deviations is generally close, and where divergent it would seem more likely that it is by accident than by the failure of application of the process. When, however, the 30 years are divided into two groups of 15, the arithmetical averages and geometrical means of the rainfall for each differ more than an inch from the average and mean of the 30; whereas according to their probable errors they should be expected only to differ about two-thirds of an inch from the truer

[1] Whether the quartile or the probable error of an average be given is of little consequence, as when the number, n, of observations (supposed of equal weight) is known, one can be deduced from the other, the quartile being probable error of average $\times\sqrt{n}$.

TABLE I.

Year.	Annual Rainfall.	Log.		Year.	Annual Rainfall.	Deviations. Yearly Amount.	Deviations. Log.
(1.)	(2.)	(3.)	(4.)	(5.)	(6.)	(7.)	(8.)
	Ins.	Ins.	Ins.		Ins.	Ins.	
1860	30·81	1·4887	..	1884	19·12	− 7·06	−0·1321
1861	22·26	1·3475	..	1873	20·09	− 6·09	−0·1106
1862	24·76	1·3938	..	1868	21·29	− 4·89	−0·0854
1863	25·44	1·4055	..	1861	22·26	− 3·92	−0·0661
1864	23·77	1·3760	..	1874	22·89	− 3·29	−0·0538
1865	26·05	1·4158	..	1870	22·91	− 3·27	−0·0536
1866	27·90	1·4456	..	1871	23·30	− 2·88	−0·0462
1867	23·87	1·3779	..	1889	23·43	− 2·75	−0·0438
1868	21·29	1·3282	..	1864	23·77	− 2·41	−0·0366
1869	24·25	1·3847	..	1867	23·87	− 2·31	−0·0357
1870	22·91	1·3600	..	1869	24·25	− 1·93	−0·0289
1871	23·30	1·3674	..	1862	24·76	− 1·42	−0·0198
1872	36·86	1·5666	..	1887	24·99	− 1·19	−0·0158
1873	20·09	1·3030	..	1863	25·44	− 0·74	−0·0081
1874	22·89	1·3596	..	1885	25·96	− 0·22	+0·0007
1875	27·19	1·4344	..	1865	26·05	− 0·13	+0·0022
1876	28·70	1·4579	..	1883	26·49	+ 0·31	+0·0095
1877	30·51	1·4844	..	1888	26·49	+ 0·31	+0·0095
1878	31·03	1·4918	..	1879	26·58	+ 0·40	+0·0110
1879	26·58	1·4246	..	1875	27·19	+ 1·01	+0·0208
1880	29·01	1·4625	..	1866	27·90	+ 1·72	+0·0320
1881	29·45	1·4691	..	1876	28·70	+ 2·52	+0·0443
1882	29·96	1·4765	..	1880	29·01	+ 2·83	+0·0489
1883	26·49	1·4231	..	1881	29·45	+ 3·27	+0·0555
1884	19·12	1·2815	..	1882	29·96	+ 3·78	+0·0629
1885	25·96	1·4143	..	1886	30·07	+ 3·89	+0·0645
1886	30·07	1·4781	..	1877	30·51	+ 4·33	+0·0708
1887	24·99	1·3978	..	1860	30·81	+ 4·63	+0·0751
1888	26·49	1·4231	..	1878	31·03	+ 4·85	+0·0782
1889	23·43	1·3698	..	1872	36·86	+10·68	+0·1530
For 30 years: Average ..	26·18	1·4136	25·92[1]				
For 30 years: Prob. error	±0·47	±0·0077	±0·46				
For 30 years: Quartile ..	±2·56	±0·0421	−2·40 +2·63				
For first 15 years: Average ..	25·10	1·3947	24·81[1]				
For first 15 years: Prob. error	±0·73	±0·0114	−0·64 +0·66				
For first 15 years: Quartile ..	±2·82	±0·0443	−2·40 +2·67				
For second 15 years: Average ..	27·27	1·4326	27·08[1]				
For second 15 years: Prob. error	±0·55	±0·0095	−0·59 +0·60				
For second 15 years: Quartile ..	±2·12	±0·0368	−2·21 +2·39				

[1] These are the *geometric means*. If hyperbolic logarithms, instead of common logarithms, had been used (as suggested by MacAlister's paper), the same resulting figures would have been obtained in col. (4).

average or mean, which one must suppose to be given by the whole 30 years. This suggests that the rainfall is subject to a period of deficiency or excess whose law differs distinctly from that yielding the accidental variations, though it may be that the difference is not too great to be so accounted for.

The occurrence of three rainfalls in the 30 years that should occur once in 11 years shows a good agreement between theory and fact; but the circumstance that one fall has occurred deviating to such a degree from the mean

TABLE II.

Coefficient.	Probability Integral for		Number of times Quartile × Coeff. occurs by		Coefficient.	Probability Integral for		Number of times Quartile × Coeff. occurs by	
	100 years.	30 years.	Rainfall.	Logarithms.		100 years.	30 years.	Rainfall.	Logarithms.
Minus.					Plus.				
∞ to 4½	·1	·0	0	0	0 to ½	13·2	4·0	4	6
4½ „ 4	·2	·1	0	0	½ „ 1	11·8	3·5	2	1
4 „ 3½	·6	·2	0	0	1 „ 1½	9·4	2·8	3	4
3½ „ 3	1·2	·4	0	1	1½ „ 2	6·7	2·0	4	4
3 „ 2½	2·5	·7	1	1	2 „ 2½	4·3	1·3	0	0
2½ „ 2	4·3	1·3	1	1	2½ „ 3	2·5	·7	0	0
2 „ 1½	6·7	2·0	2	1	3 „ 3½	1·2	·4	0	0
1½ „ 1	9·4	2·8	4	4	3½ „ 4	·6	·2	0	1
1 „ ½	11·8	3·5	4	3	4 „ 4½	·2	·1	1	0
½ „ 0	13·2	4·0	4	3	4½ „ ∞	·1	·0	0	0
					Totals	100	30	30	30

as should only happen accidentally once in 160 years shows either that the theory is only partially applicable,[1] or else that that fall was of an exceptional nature, such as cannot be expected to recur (at Sunderland) in the lifetime of any one now living.

It is obvious that the theory is not applicable to the case of *daily* rainfall, for it can only apply in cases in which the most frequently recurring numbers are those nearest to the average; and in the case of *daily* rainfall the most frequent numbers are the least possible, namely 0·00. For the same, but weakened, reason the formulæ will not apply to *weekly* rainfall, because in this also 0·00 is not an infrequent amount, though the failure of applicability is less obvious in this case. In the totals for *monthly* rain 0·00 rarely, if ever, occurs; and therefore there is more likelihood of the formulæ applying; and so as we increase the period the greater is the chance of applicability of the formulæ, till in the case of *yearly* rain, it might fairly be expected to apply. The present investigation is therefore undertaken to show whether the probability rules do apply or not to *yearly* rain. It would seem that they are very fairly applicable. In all cases where they are found not to apply, there must be some law or laws which prevent their application; and it is the province of Meteorology to find out what such laws are.

1 This paper having been submitted to Dr. MacAlister, he writes as follows on this point: "I think your remark, 'that the theory is only partially applicable' is probably right. Where there is a likelihood of an undulatory period in the rainfalls, you would have to have a total number of observations considerably greater than that of one or two periods before you could expect the theory to accord well with fact."

DISCUSSION.

Mr. BLANFORD said that Mr. Backhouse's paper was of importance, because it afforded us occasion to clarify our ideas as to the meaning of different kinds of mean values, and therefore of their applicability under different circumstances. The geometric mean to which the author had drawn attention might in many cases express more accurately than the ordinary average (or arithmetical mean) the most probable rainfall of any given future year; but it could by no means be substituted for that average in dealing with most of those problems that take the average rainfall as one of their data, such as all questions of water supply, and in relation to agriculture, drainage, &c. The arithmetical mean expresses that quantity which, if repeated regularly year after year, would, in the course of a great many years, yield the same total as the sum of the actual variable rainfalls of those years. Here the geometric mean would be out of place. Mr. Backhouse stated that it was found in the case of British rainfall "that the excess in the wettest year is one and a half times the average, and the defect in the driest year is not more than 65 per cent. of the average—which is the same as the geometric statement that three seconds is equally likely with two-thirds the average." There seems to be a little apparent inconsistency in these alternative statements, but the meaning is probably that a rainfall of 65 per cent. of the average (not a deficiency of 65 per cent.) is as likely as one of 150 per cent.; or in general terms that the rainfall of the driest year bears the same ratio to the average as the average does to the rainfall of the wettest year. In this quotation the average referred to would seem to be the arithmetical mean. But the author's remark that it illustrates the justness of the theory would be valid only on the supposition that it is the geometrical mean. It appeared on the evidence of several Indian stations with a very variable rainfall that the fall of the driest year bore a smaller ratio to the average (arithmetical mean) than that average does to the rainfall of the wettest year.

Mr. DINES did not think it would be advisable to use the geometrical instead of the arithmetical mean for the purpose of obtaining the average rainfall, but he thought the paper was a valuable one, and that the thanks of the Society were due to Mr. Backhouse for bringing the subject forward. If the methods indicated in the paper were more generally used, many errors would be avoided, and many curious theories would never be started; for a theory was sometimes based on differences in the values of averages, when a careful study of the theory of probability would show beforehand that such differences would be almost certain to occur.

THE GREAT FROST OF 1890-1891.

By CHARLES HARDING, F.R.Met.Soc.

[Read February 18th, 1891.]

This paper has been prepared at the request of the Council, and although willing to assist in the work of the Society with the hope of extending its sphere of usefulness, I cannot help feeling that some apology is necessary from me as my previous paper[1] was read so recently.

The most striking feature of the frost through which we have just passed is the very prolonged period of cold, and the very low day temperatures which were experienced throughout. There are many frosts, even of recent years, in which the temperature has fallen much lower—that is, in which the frost has been more intense; and there have also been frosts within the last few years which have been more general over the whole country; but, so far as the southern portion of England is concerned, there does not seem during the last century to have been any such prolonged period of frost as that of 1890-91.

The period dealt with is that from November 25th, 1890, to January 22nd, 1891; but before treating of that period it will be well to remind the Fellows of the very sharp frost which occurred in many parts of the country at the end of October; the shade thermometer at Greenwich registering 24°·7, which is lower than any previous record in October during the last half century. This was followed by a spell of wet and mild weather which continued until the last week of November, when the whole country was suddenly plunged into mid-winter, severe frost and snowstorms being experienced in all parts of our islands, whilst very intense cold occurred at some of our southern coast stations. In parts of Kent and Surrey the thermometer in the screen fell almost to zero (0°), and even at Jersey it registered 16°. At Greenwich the shade temperature on the 29th fell to 18°·3, which is the lowest reading recorded in November during the last 100 years, whilst in 20 winters during the last 40 years the thermometer has not fallen as low.

The material used by me has been obtained almost entirely from the Stations of the Meteorological Office and from those of the Royal Meteorological Society, and no temperatures are quoted which are in any way questionable or doubtful, and all the values are from thermometers exposed in authorised screens.

Fig. 1[2] (p. 108) has been drawn entirely from the stations used by the

[1] "The Cold Period at the beginning of March 1890." *Quarterly Journal*, Vol. XVI. p. 152.

[2] Figs. 1, 2 and 3 are reproduced from the *Journal of the Royal Agricultural Society*, March 31st, 1891, by permission of the Council of that Society.—Ed.

Meteorological Office in the compilation of its *Weekly Weather Report*, some of the results being supplied to the Office by the Royal Meteorological Society, and some by the Scottish Meteorological Society. In all, the returns from 77 stations have been used in the preparation of this diagram. The means have been obtained from the means of the maximum and minimum readings, and give the mean temperature for the whole period of 59 days, from November 25th, 1890, to January 22nd, 1891. Isotherms have been drawn for each 2°. It will be seen that a very large portion of the South-east of England had a mean temperature for the whole period below 30°, whilst at Cambridge the mean was 28°·5, and at Hillington in Norfolk it was 28°·6. The whole of the Midlands and a very large part of the Southern and South-western Districts of England had a mean temperature below the freezing point; whilst at sea-side stations on the Coast of Kent, Sussex, and Hampshire, the mean was only 32°.

This chart shows very clearly the great difference of temperature between various parts of the United Kingdom for the period of the frost. The warmest weather occurred in the extreme north and west of our Islands, and the exceptionally high temperature which prevailed over Scotland is quite phenomenal. In the extreme North of Scotland as well as in the West of Ireland the mean was 10° higher than in the South-east of England.

To secure accuracy in drawing the isotherms, the means given on the chart have been corrected for height above sea-level by allowing 1° decrease for every 300 feet, but no correction has been applied to the means given in the Tables.

Fig. 2 shows the deficiency of the means from the average value for the period, obtained from 20 years' observations. The greatest difference from the average at any of the Meteorological Office stations was 10°·6 at Strathfield Turgiss, whilst a large part of the country in the Southern Midlands and the South of England had the mean temperature for the whole period of 59 days as much as 10° or more below the average. In the North of England however the deficiency did not amount to 5°, and in the extreme North of Scotland it was less than 1°.

The following Tables contain observations from the Royal Meteorological Society's Stations and from all the Weekly Weather Report Stations of the Meteorological Office. They give certain details which will serve to test the severity of the frost. The stations are grouped together in districts in accordance with the system adopted by the Meteorological Office, which is also followed by the Society in the *Meteorological Record*. The whole period of the frost from November 25th, 1890, to January 22nd, 1891, is dealt with for each station. In the body of the Table N. represents November, D. December, and J. January.

The following are a few of the most salient features gathered from the accompanying Tables :—

MEAN MAXIMUM TEMPERATURE.

Highest.

°	°
46·7 at Valencia, in S.W. of Ireland.	45·1 at Roche's Point.
45·1 ,, Scilly.	43·1 ,, Stornoway.
42·5 ,, Sumburgh Head.	42·5 ,, Laudale.

Station.	Whole Period.				Minimum.							Maximum.							
					Absolute.				32° or below.			Absolute.		32° or below.			Lowest Day.		
	Mean Max.	Mean Min.	Mean of Max. and Min.	Difference from Average.		Date.	Below 10°. No. of Days.	Below 20° (including below 10°). No. of Days.	No. of Days.	Longest consecutive period and limiting dates. Days.	Longest consecutive period and limiting dates. Date.		Date.	No. of Days.	Longest consecutive period and limiting dates. Days.	Longest consecutive period and limiting dates. Date.		Date.	40° and above. No. of Days.
SCOTLAND, N.	°	°	°	°	°							°					°		
Sumburgh Head	42·5	36·2	39·4	—0·5	27	J. 21	..	..	9	3	J. 4–6	53	D. 1	1	1	J. 21	32	J. 21	51
Stornoway	43·1	34·1	38·6	—0·7	25	D. 7 J. 21 & 22	..	..	22	5	D. 6–10	53	N. 30, D. 1	..	..	..	34	J. 21	51
Wick	41·9	34·1	38·0	—0·9	20	J. 7	..	..	21	8	J. 3–10	54	D. 1	..	..	..	34	J. 22	41
Lairg	38·5	27·9	33·2	—4·2	9	J. 7	1	5	47	14	D. 16–29	55·5	N. 30, D. 1	5	2	D. 6 & 7	28	N. 27, J. 7	19
Glencarron	39·3	29·8	34·6	—2·6	18·8	J. 22	..	1	43	10	D. 31–J. 9	52·1	D. 1	1	1	D. 17	32	D. 17	25
Fort Augustus	40·7	30·8	35·8	—2·6	18·0	N. 27, J. 22	..	2	37	9	J. 2–J. 10	53·9	D. 2	2	1	N. 27, D. 10	31	N. 27	31
Fort William	41·6	33·0	37·3	—1·7	22·0	N. 27	..	..	26	5	D. 6–10	53·1	D. 1	2	2	N. 27 & 18	29	N. 27	34
SCOTLAND, E.																			
Nairn	40·7	30·4	35·6	—2·3	19	N. 27	..	1	37	6	D. 6–11 D. 17–22 J. 5–10	57	D. 1	..	..	..	33	D. 7	29
Aberdeen	39·8	32·3	36·1	—1·4	15	D. 22	..	1	28	7	D. 19–25 J. 5–11	55	D. 1	6	2	N. 27 & 28 J. 6 & 7	31	D. 21, J. 7	30
Braemar	36·4	27·4	31·9	—2·3	8·0	J. 7	2	10	46	18	D. 24–J. 10	51·8	D. 1	11	3	N. 26–28	24·8	N. 27	8
Ochtertyre	39·2	29·1	34·2	—2·9	18	J. 9	..	2	43	14	D. 16–29	52	D. 1, J. 12	5	2	D. 18 & 19	28	D. 19	23
Leith	40·5	31·1	35·8	—2·2	20·8	J. 8	..	..	35	8	D. 18–25	56·5	D. 1	1	1	D. 13	31·6	D. 13	30
Marchmont	37·5	28·6	33·1	—2·8	16	J. 18	..	5	43	8	J. 15–22	50	D. 1	6	2	D. 13 & 14 D. 18 & 19	29	D. 14	15
SCOTLAND, W.																			
Laudale	42·5	33·4	38·0	—1·9	22·7	J. 21	..	..	22	4	D. 16–19 J. 4–7	57·6	D. 1	..	..	..	32·3	N. 27	38
Glasgow	39·6	30·7	35·2	—3·5	22·3	N. 27	..	..	29	7	J. 4–10	51·0	D. 1	1	1	D. 19	30·4	D. 19	27

TABLE I.—AIR TEMPERATURES, NOVEMBER 25TH, 1890, TO JANUARY 22ND, 1891 (59 DAYS).—*Continued.*

Station.	Whole Period. Mean Max.	Whole Period. Mean Min.	Whole Period. Mean of Max. and Min.	Whole Period. Difference from Average.	Minimum. Absolute.	Minimum. Absolute. Date.	Minimum. Below 10°. No. of Days.	Minimum. Below 20° (including below 10°). No. of Days.	Minimum. 32° or below. No. of Days.	Minimum. 32° or below. Lowest consecutive period and limiting dates. Days.	Minimum. 32° or below. Lowest consecutive period and limiting dates. Date.	Maximum. Absolute.	Maximum. Absolute. Date.	Maximum. 32° or below. No. of Days.	Maximum. 32° or below. Longest consecutive period and limiting dates. Days.	Maximum. 32° or below. Longest consecutive period and limiting dates. Date.	Maximum. Lowest Day.	Maximum. Lowest Day. Date.	Maximum. 40° and above. No. of Days.
SCOTLAND, W.—*Continued.*	°	°	°	°	°							°					°		
Ardrossan	41·2	33·0	37·1	−2·0	25	N. 28	..	..	28	7	D. 16–22	51	D. 1	..	..	..	33	N. 27	38
Glenlee	38·2	29·7	34·0	−4·1	15·2	D. 21	..	4	42	9	D. 6–14	52	D. 1	6	3	D. 19–21	26	D. 21, J. 22	22
Douglas (Isle of Man)	41·1	33·7	37·4	−3·5	19	D. 20	..	1	19	6	J. 5–10	51·2	D. 1	1	1	D. 20	30	D. 20	36
ENGLAND, N.E.																			
Alnwick Castle	38·3	30·1	34·2	−3·7	17	J. 17	..	6	35	10	J. 1–10	51	N. 30	9	2	Var.	27	D. 13	24
Rothbury	..	..	..	..	10·4	J. 18	..	9	37	7	J. 5–11	51·0	D. 2	7	3	D. 12–14	28·8	D. 13	19
Shields	38·8	29·6	34·2	−4·7	15	J. 19	..	2	39	9	D. 18–26 J. 14–22	49	N. 30, D. 1	4	2	D. 21 & 22	27	J. 18	27
Durham	37·2	27·9	32·6	−5·4	8·9	J. 18	1	5	45	18	D. 9–26	48·9	D. 1	8	3	D. 12–14	26·3	J. 18	15
Ushaw	..	..	..	..	14·5	J. 19	..	4	46	17	D. 9–25	48·2	D. 1	10	3	D. 11–13	27·5	D. 19	9
Rounton	..	..	..	..	0·6	J. 18	1	10	49	16	D. 27–J. 11	47·1	J. 12	7	2	D. 13–14 J. 17–18	24·9	J. 18	12
Scarborough	37·3	30·6	34·0	−4·0	16·3	J. 19	..	2	35	9	D. 18–26	47·6	J. 12	5	2	D. 22–23 J. 18–19	29·8	J. 19	13
Driffield	..	..	..	..	10·1	J. 19	..	12	48	26	D. 18–J. 12	45·2	J. 13	8	3	D. 18–20	27·7	J. 18	8
York	36·5	27·0	31·8	−6·6	10	J. 18	..	7	51	35	D. 10–J. 13	46	D. 4	10	4	D. 19–22	26	J. 18	14
Spurn Head	37·2	30·3	33·8	−4·7	22	J. 19	..	..	41	15	D. 29–J. 12	45	D. 4	3	2	D. 23 & 24	30	J. 18	11
Lincoln	..	..	..	..	12·6	J. 19	..	7	52	43	D. 11–J. 22	43·1	D. 4	19	4	D. 22–25	24·4	D. 22	6
ENGLAND, N.W.																			
Scaleby	..	..	..	..	15·1	D. 14 & 22	..	9	48	17	D. 9–25	49·9	D. 1	8	4	D. 18–21	28·2	D. 12	16
Newton Reigny	36·2	26·5	31·4	−6·2	13·0	J. 18	..	13	46	19	D. 6–24	49·8	D. 2	12	4	D. 18–21	23·9	D. 13	12
Windermere	..	..	..	..	15·1	J. 18	..	10	45	19	D. 8–26	47·4	J. 13	9	5	D. 18–22	25·9	D. 13	11

Station.	Mean Max.	Mean Min.	Mean of Max. and Min.	Difference from Average.	Minimum. Absolute.	Date.	Below 10°. No. of Days.	Below 20° (including below 10°). No. of Days.	32° or below. No. of Days.	Lowest consecutive period and limiting dates. Days.	Date.	Maximum. Absolute.	Date.	32° or below. No. of Days.	Lowest consecutive period and limiting dates. Days.	Date.	Lowest Day.	Date.	40° and above. No. of Days.
ENGLAND, N.W.—*Continued.*	°	°	°	°	°							°					°		
Aysgarth	..	..	..	..	7·9	J. 18	2	11	51	20	D. 6–25	47·5	D. 1, J. 13	14	3	D. 12–14 D. 18–20	25·8	D. 13	10
Stonyhurst	36·5	28·0	32·3	— 6·3	11·6	J. 19	..	7	45	15	D. 18–J. 1	46·1	J. 20	8	3	D. 19–21	27·1	D. 14	13
Blackpool	36·6	29·1	32·9	— 7·9	17·6	D. 22	..	4	39	15	D. 12–J. 6	44·2	D. 1 & 3	7	4	D. 18–21	27·6	D. 12, 19	16
Bolton	..	..	..	..	14·9	J. 18	..	7	47	18	D. 9–26	43·4	D. 1	9	4	D. 18–21	25·5	D. 20	10
Manchester	35·9	28·0	32·0	— 7·1	13·0	D. 20	..	6	45	13	D. 11–23	45·3	D. 5	9	3	J. 17–19	27·2	D. 13	9
Liverpool	37·1	29·3	33·2	— 7·0	17	D. 21	..	3	41	15	D. 12–26	48	J. 22	9	5	D. 18–22	26	J. 20	19
Northwich	..	..	..	..	5·0	D. 22	1	9	56	47	D. 7–J. 22	45·0	J. 12 & 20	4	..	..	29·0	D. 12	15
Llandudno	40·3	31·7	36·0	— 5·9	20·0	D. 20, 21, J. 13	..	..	29	11	D. 12–22	51·7	D. 1	2	..	..	30·0	D. 20	30
Holyhead	41·9	34·5	38·2	— 5·1	26	D. 22, 31 J. 1, 18	..	..	22	11	D. 13–23	51	D. 1	0	..	..	34	D. 28	39
ENGLAND, E.																			
Hillington	33·7	22·9	28·3	— 9·6	5·2	J. 18	6	19	53	26	D. 9–J. 3	44·1	D. 4	20	6	J. 6–11 D. 18–23	26·3	J. 10	5
Yarmouth	35·2	27·9	31·6	— 7·3	19	J. 11	..	1	47	29	D. 15–J. 12	43	D. 3 & 4	15	4	J. 16–19	28	D. 29	8
Somerleyton	..	..	..	..	4·1	J. 10	2	12	48	16	D. 10–25	44·2	D. 3	11	3	J. 8–10	28·2	D. 29	13
Geldeston	35·6	24·0	29·8	— 9·1	6·7	J. 11	2	15	52	26	D. 9–J. 3	44	D. 9	11	2	N. 27 & 28 D. 29 & 30	28·6	D. 30	12
Lowestoft	..	..	..	..	13·2	J. 11	..	2	43	9	J. 14–22	50·3	N. 25	4	2	J. 10–11	27·3	D. 30	17
Cambridge	34·0	22·3	28·2	—10·0	4	D. 22	3	21	57	48	D. 6–J. 22	44	D. 4, J. 20	25	11	D. 13–23	25·8	D. 22	8
Great Thurlow	..	..	..	..	5·0	D. 22	3	19	54	37	D. 7–J. 12	42·6	D. 4	27	5	N. 26–30 D. 15–19 J. 6–10	25·9	D. 30	4

TABLE I.—AIR TEMPERATURES, NOVEMBER 25TH, 1890, TO JANUARY 22ND, 1891 (59 DAYS).—*Continued.*

Station.	Whole Period.				Minimum.							Maximum.							
	Mean Max.	Mean Min.	Mean of Max. and Min.	Difference from Average.	Absolute.		Below 10°. No. of Days.	Below 20° (including below 10°). No. of Days.	32° or below.			Absolute.		32° or below.			Lowest Day.		40° and above. No. of Days.
						Date.			No. of Days.	Longest consecutive period and limiting dates. Days.	Date.		Date.	No. of Days.	Longest consecutive period and limiting dates. Days.	Date.		Date.	
ENGLAND, E.—*Continued.*	°	°	°	°	°							°					°		
Bennington	..	..	..	..	14·4	D. 20	..	13	56	38	D. 6–J. 12	42·1	J. 21	21	6	D. 15–20	25·8	D. 30	4
Rothamsted	33·8	23·4	28·6	−9·2	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
St. Albans	..	..	..	..	12·7	D. 22	..	16	55	38	D. 7–J. 13	45·3	N. 25	19	4	D. 22–25 D. 27–30	24·9	D. 30	7
Chelmsford	..	..	..	..	4·3	D. 22	4	19	53	36	D. 9–J. 13	48·6	D. 6	20	5	D. 15–19	27·3	D. 30	8
MIDLAND COUNTIES.																			
Harrogate	..	..	..	..	8·3	J. 18	1	8	50	35	D. 9–J. 12	44·9	D. 1	14	3	Various	26·4	D. 19, J. 18	7
Wakefield	..	..	..	..	7·3	J. 19	2	6	46	15	D. 11–25	45·5	D. 2 & J. 20	9	5	D. 19–23	25·4	D. 14	15
Bawtry	35·3	25·7	30·5	−8·5	9	J. 18	1	10	56	50	D. 4–J. 22	44	N. 25, D. 2	12	7	D. 18–24	27	D. 22–J. 18	10
Hodsock	..	..	..	..	6·7	J. 18	2	11	54	47	D. 7–J. 22	45·5	J. 12	11	3	D. 18–20	28·5	D. 20	10
Buxton	..	..	..	..	3·2	J. 19	4	13	55	38	D. 6–J. 12	43·6	D. 4	27	8	D. 16–23	23·1	D. 21	6
Southwell	..	..	..	..	4·7	D. 22	3	12	54	47	D. 7–J. 22	44·1	D. 4–J. 12	11	3	D. 18–20 D. 22–24	26·2	D. 22	10
Belper	..	..	..	..	7·0	J. 19	2	10	53	37	D. 7–J. 12	43·7	J. 13	20	8	D. 18–25	25·3	D. 22	6
Cheadle	34·4	25·9	30·2	−7·4	13·9	J. 19	..	6	56	30	D. 5–J. 13	41·9	D. 4	21	4	J. 6–9	26·1	D. 22	7
Burton-on-Trent	..	..	..	..	2·8	D. 22	3	11	51	36	D. 9–J. 13	45·7	J. 13	13	7	D. 18–24	24·8	D. 21	13
Loughborough	35·1	24·8	30·0	−7·9	7·3	J. 19	3	10	54	45	D. 7–J. 20	43·6	D. 1	16	8	D. 18–25	24·9	D. 22	10
Stamford	34·3	23·1	28·7	−9·6	1	J. 18	4	15	56	47	D. 7–J. 22	44	D. 4	23	8	D. 13–20	23	D. 22	10
Churchstoke	35·0	25·0	30·0	−8·3	9·2	D. 21, J. 18	2	13	52	38	D. 6–J. 12	46·1	D. 1	21	7	D. 16–22	25·0	D. 21	13
Stokesay	..	..	..	..	0·6	D. 22	5	13	55	38	D. 6–J. 12	45·2	N. 20	19	8	D. 16–23	24·7	J. 21	11
Uppingham	..	..	..	..	15·1	J. 19	..	8	53	24	D. 11–J. 3	42·0	J. 13	27	5	D. 12–16 D. 27–31	25·4	D. 25	4
Kenilworth	..	..	..	..	7·7	D. 22	2	12	53	37	D. 7–J. 12	43·0	J. 13	26	8	D. 10–25	26·3	D. 30	7

TABLE I.—AIR TEMPERATURES, NOVEMBER 25TH, 1890, TO JANUARY 22ND, 1891 (59 DAYS).—*Continued.*

Station.	Whole Period.				Minimum.							Maximum.							
					Absolute.				32° or below.			Absolute.		32° or below.			Lowest Day.		
	Mean Max.	Mean Min.	Mean of Max. and Min.	Difference from Average.		Date.	Below 10°. No. of Days.	Below 20° (including below 10). No. of Days.	No. of Days.	Longest consecutive period and limiting dates. Days.	Date.		Date.	No. of Days.	Longest consecutive period and limiting dates. Days.	Date.		Date.	40° and above. No. of Days.
MID. COUNTIES—*Continued.*	°	°	°	°	°							°					°		
Burghill	..	..	..	..	6·1	D. 22	2	11	52	38	D. 7–J. 13	46·6	J. 20	17	4	D. 19–22	27·8	D. 30	12
Great Malvern	..	..	..	..	16·6	J. 19	..	5	50	28	D. 7–J. 3	44·9	J. 22	19	4	D. 11–14 D. 28–31	26·1	D. 31	11
Hereford	35·4	25·1	30·3	— 8·3	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Ross	..	..	..	..	7·3	J. 19	2	11	53	46	D. 7–J. 21	45·7	J. 22	19	3	Various	26·5	D. 30	10
Cheltenham	..	..	..	..	5·5	D. 22	2	14	54	47	D. 6–J. 21	45·2	J. 20	22	3	Various	24·5	J. 18	10
Oxford	33·8	23·9	28·9	—10·2	8	D. 23	2	12	54	38	D. 7–J. 13	43	D. 4, J. 22	25	13	D. 13–25	24	D. 13 & 22	9
Cirencester	34·7	22·6	28·7	— 9·9	8	D. 23	2	15	55	38	D. 7–J. 13	44	J. 22	20	6	D. 22–27	24	D. 30	11
Berkhamsted	..	..	..	..	11·1	D. 22	..	16	53	37	D. 7–J. 12	42·9	J. 20 & 21	24	6	D. 15–20	25·2	D. 30	5
ENGLAND, S.																			
London (Old Street, E.C.)	..	..	..	..	17·2	D. 20	..	1	48	35	D. 10–J. 13	44·9	J. 20	13	2	Various	27·0	D. 30	10
„ Brixton	35·2	25·6	30·4	— 8·8	14	D. 22, J. 11	..	8	52	35	D. 10–J. 13	45	D. 4	16	3	J. 14–16	25	J. 11	12
„ Camden Square	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Kew Observatory	..	..	..	..	10·7	D. 23	..	8	52	36	D. 9–J. 13	43·8	D. 4	22	7	D. 13–19	24·1	D. 14	8
West Norwood	..	..	..	..	12·5	J. 10	..	13	52	34	D. 10–J. 12	44·1	J. 21	25	10	D. 11–20	25·1	N. 28	9
Addiscombe	..	..	..	..	9·6	J. 10	1	20	55	38	D. 7–J. 13	44·6	J. 20	24	6	D. 14–19	25·8	D. 30	8
Addington Hills	..	..	..	..	11·2	J. 10	..	18	58	47	D. 7–J. 22	43·4	J. 20	27	6	D. 14–19	24·0	D. 30	6
Waddon	33·9	21·8	27·9	..	1·0	N. 29	6	23	55	38	D. 7–J. 13	44·0	J. 20	24	10	D. 10–19	25·0	D. 14	9
Beddington	34·0	21·4	27·7	..	2·3	N. 28	4	24	56	47	D. 7–J. 22	44·0	J. 20	25	10	D. 10–19	25·0	D. 14	9
Kenley	33·3	23·1	28·2	..	9	N. 29	2	20	53	28	D 7–J. 3	43·5	J. 20	31	10	D. 10–19	24	D. 30	5
Greenwich[1]	33·5	25·0	29·3	— 9·5[2]	12·0	J. 10	..	10	52	35	D. 10–J. 13	43·8	J. 20	26	10	D. 10–19	23·7	D. 22	3

[1] Worked up from Climatological Series of Observations and comparable with others in Table.
[2] Difference from Mean of 60 years (1814 to 1873).

TABLE I.—Air Temperatures, November 25th, 1890, to January 22nd, 1891 (59 Days.)—*Continued.*

Station.	Whole Period.				Minimum.							Maximum.					Lowest Day.		
	Mean Max.	Mean Min.	Mean of Max. and Min.	Difference from Average.	Absolute.		Below 10°. No. of Days.	Below 20° (including below 10°). No. of Days.	32° or below.			Absolute.		32° or below.					40° and above. No. of Days.
						Date.			No. of Days.	Longest consecutive period and limiting dates. Days.	Date.		Date.	No. of Days.	Longest consecutive period and limiting dates. Days.	Date.		Date.	
England, S.—*Continued.*	°	°	°	°	°							°					°		
Chatham	..	..	..	..	13	N. 29, D. 15	..	12	52	37	D. 7–J. 12	44	J. 20	22	4	D. 14–18	26	D. 30	10
Reading	..	..	..	..	9·0	D. 23	1	22	57	47	D. 7–J. 22	41·0	D. 4	36	11	D. 10–20	21·2	D. 14	2
Tunbridge Wells	..	..	..	..	8·7	N. 29	1	12	55	38	D. 7–J. 13	43·2	J. 20	23	5	D. 15–19	23·9	D. 30	7
Strathfield Turgiss	34·2	22·4	28·3	—10·6	7·5	D. 22	1	19	52	37	D. 8–J. 13	43·9	D. 5	23	7	D. 11–17	22·5	D. 22	10
Stowell	34·7	24·7	29·7	—10·1	11·9	J. 19	..	12	52	20	D. 7–26	46·9	D. 4	19	3	Various	25·1	D. 30	9
Harestock	..	..	..	..	11·0	D. 23	..	19	53	28	D. 7–J. 3	44·2	J. 21	21	4	D. 14–17 D. 28–31	24·4	N. 28	7
Parkstone	..	..	..	..	14·3	J. 19	..	8	54	37	D. 7–J. 12	46	J. 22	15	3	N. 27–29 D. 28–30 J. 17–19	25·6	N. 28	11
Margate	..	..	..	..	15·6	J. 9	..	6	50	18	J. 5–22	43·6	D. 4	13	2	Various	26·4	D. 30	7
Dungeness	37·1	26·7	31·9	— 9·2	12	D. 31, J. 10	..	8	48	22	D. 23–J. 13	45	J. 22	12	2	..	28	D. 30, J. 9	20
Bexhill	..	..	..	..	14·9	N. 29	..	6	50	23	D. 10–J. 1	43·2	J. 13	12	3	D. 28–30	26·2	D. 30	13
Hastings	36·1	28·1	32·1	— 8·6	16·3	N. 28	..	3	46	10	D. 10–19 D. 22–31	42·4	J. 3	12	3	D. 28–30 J. 17–19	27·1	D. 30	15
Eastbourne	..	..	..	..	17	N. 28	..	5	43	11	D. 10–20	50	N. 26	5	2	J. 17 & 18	27·6	D. 30	27
Brighton	..	..	..	..	17·5	D. 31	..	3	48	23	D. 10–J. 1	49·4	N. 25	9	3	D. 18–20	26·4	D. 30	17
Worthing	..	..	..	..	14·9	N. 29	..	7	53	37	D. 8–J. 13	44·0	J. 12	12	3	D. 28–30	26·7	D. 30	15
Portsmouth	..	..	..	..	16·5	N. 29	..	3	49	27	D. 8–J. 3	45·5	J. 20	11	3	D. 28–30	27·4	D. 30	16
Southampton	36·2	25·7	31·0	— 8·4	16	J. 19	..	12	51	28	D. 7–J. 3	46·1	J. 22	8	2	D. 29 & 30 J. 6 & 7	26·6	N. 28	12
Ventnor	..	..	..	..	20·7	J. 18	..	..	32	5	N. 26–30 D. 15–19	45·7	D. 3	3	..	..	25·7	N. 28	24

TABLE I.—AIR TEMPERATURES, NOVEMBER 25TH, 1890, TO JANUARY 22ND, 1891 (59 DAYS).—*Continued.*

Station.	Whole Period.				Minimum.							Maximum.							
	Mean Max.	Mean Min.	Mean of Max. and Min.	Difference from Average.	Absolute.		Below 10°. No. of Days.	Below 20° (including below 10°). No. of Days.	32° or below.			Absolute.		32° or below.			Lowest Day.		40° and above. No. of Days.
						Date.			No. of Days.	Longest consecutive period and limiting dates. Days.	Date.		Date.	No. of Days.	Longest consecutive period and limiting dates. Days.	Date.		Date.	
ENGLAND, S.—*Continued.*	°	°	°	°	°							°					°		
Totland Bay, I. W.	..	..	..	..	19	D. 31, J. 18 & 19	..	3	47	24	D 11–J. 3	46	J. 20 & 22	11	2	Various	27	N. 28	16
Hurst Castle	37·6	27·8	32·7	−8·7	19	D. 15, J. 20	..	2	43	16	J. 5–20	45	J. 22	7	2	..	28	N. 28	15
Weymouth	..	..	..	..	19·0	J. 18	..	1	37	8	D. 14–21 J. 5–12	46·0	J. 22	9	3	N. 27–29	28·0	N. 28	22
Rousdon	..	..	..	..	15·3	J. 18	..	7	46	15	D. 11–25	44·0	D. 1, J. 22	12	3	N. 27–29 D. 28–30	25·2	D. 30	20
ENGLAND, S.W.																			
Aberystwith	..	..	..	..	17·9	J. 18	..	2	35	11	D. 12–22	48·2	D. 1	0	..	..	32·3	J. 18	33
Llandovery	36·9	24·0	30·5	−9·7	7	J. 18	2	16	53	42	D. 12–J. 22	46	J. 22	11	3	D. 12–14 D. 28–30	28	J. 18	16
Carmarthen	..	..	..	..	13·5	J. 18	..	8	45	12	D. 11–22	47·0	D. 1	2	..	..	31·1	D. 30	22
Pembroke	41·3	33·1	37·2	−5·7	19	D. 31	..	1	26	6	D. 27–J. 1	51	D. 1	1	1	..	32	D. 30	39
Weston-super-Mare	..	..	..	..	15·0	J. 19	..	5	47	20	D. 7–26	46·0	J. 13 & 20	4	..	..	27·2	D. 30	21
Ilfracombe	..	..	..	..	21·3	D. 31	..	0	24	7	D. 12–18	49·8	J. 22	1	..	..	29·9	D. 30	37
Arlington	37·5	27·3	32·4	−8·0	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
South Molton	..	..	..	..	9·5	J. 19	1	11	47	22	D. 12–J. 2	47·5	J. 22	9	3	D. 28–30	27·0	D. 30	16
Cullompton	36·9	26·0	31·5	−9·5	10·1	J. 19	..	11	49	17	D. 28–J. 13	47·0	J. 22	12	3	D. 28–30	27·1	D. 30	17
Bude	..	..	..	..	17·6	J. 8	..	4	40	11	J. 5–15	47·0	N. 25, D. 3, J. 22	4	2	D. 30 & 31	27·5	D. 31	31
Brampford Speke	..	..	..	..	12·7	J. 19	..	6	47	15	D. 12–26	46·1	J. 22	10	2	Various	27·8	D. 30	15
Exeter	..	..	..	..	13·0	J. 19	..	4	45	15	D. 12–26	48·7	J. 22	8	2	Various	27·[illegible]	[illegible] 7	27

TABLE I.—AIR TEMPERATURES, NOVEMBER 25TH, 1890, TO JANUARY 22ND, 1891 (59 DAYS).—*Continued.*

Station.	Whole Period. Mean Max.	Whole Period. Mean Min.	Whole Period. Mean of Max. and Min.	Whole Period. Difference from Average.	Minimum. Absolute.	Minimum. Absolute. Date.	Minimum. Below 10°. No. of Days.	Minimum. Below 20° (including below 10°). No. of Days.	Minimum. 32° or below. No. of Days.	Minimum. 32° or below. Longest consecutive period and limiting dates. Days.	Minimum. 32° or below. Longest consecutive period and limiting dates. Date.	Maximum. Absolute.	Maximum. Absolute. Date.	Maximum. 32° or below. No. of Days.	Maximum. 32° or below. Longest consecutive period and limiting dates. Days.	Maximum. 32° or below. Longest consecutive period and limiting dates. Date.	Maximum. Lowest Day.	Maximum. Lowest Day. Date.	40° and above. No. of Days.
ENGLAND, S.W.—*Continued.*	°	°	°	°	°							°					°		
Princetown	..	..	..	..	12·4	J. 18	..	17	52	22	D. 12–J. 2	47·3	D. 2	16	4	N. 26–29 D. 28–31	24·7	D. 30	16
Ashburton	..	..	..	..	18·6	J. 19	..	3	40	9	J. 5–13	47·9	J. 3	7	3	D. 28–30	25·6	D. 30	26
Sidmouth	..	..	..	..	18·0	J. 19	..	3	42	11	D. 12–22	48·3	J. 22	7	2	D. 29 & 30 J. 17 & 18	27·0	D. 30	26
Babbacombe	..	..	..	..	14·0	J. 19	..	2	31	5	N. 26–30 D. 27–31	48·9	J. 22	3	..	..	29·1	D. 30	30
Falmouth	42·1	32·3	37·2	—6·8	22·3	N. 29	..	..	27	5	N. 26–30 D. 28–31	49·9	J. 22	2	..	..	31·6	D. 30	42
Plymouth	40·5	30·2	35·4	—7·3	19·8	J. 19	..	1	37	9	J. 5–13	49·5	J. 22	3	Var.	..	29·5	D. 30	37
Prawle Point	40·9	31·3	36·1	—6·5	19	N. 27	..	1	31	9	J. 5–13	49	J. 1	4	1	..	28	N. 29	36
CHANNEL ISLANDS.																			
Scilly	45·1	38·1	41·6	—5·2	29	N 28, J. 17 & 18	..	..	13	4	N. 24–30 J. 17–20	51	D. 10	..	..	..	35	J. 6	55
Guernsey	..	..	..	..	25·5	N. 29	..	..	18	5	N. 27–D. 1	48·7	J. 1	0	..	..	33·7	J. 17	33
Jersey	41·2	31·2	36·3	—6·9	12·2	J. 18	..	3	32	9	D. 24–J. 1	50	J. 22	..	..	..	37·3	D. 16	34
IRELAND, N.																			
Malin Head	42·8	35·8	39·3	—1·2	30	J. 8 & 18	..	..	11	2	N. 27 & 28 D. 17 & 18 J. 7 & 8 J. 18 & 19	53	N. 30, D. 1	..	..	..	35	J. 7	46

TABLE I.—AIR TEMPERATURES, NOVEMBER 25TH, 1890, TO JANUARY 22ND, 1891 (59 DAYS).—*Continued.*

Station.	Whole Period.				Minimum.							Maximum.							
	Mean Max.	Mean Min.	Mean of Max. and Min.	Difference from Average.	Absolute.		Below 10°. No. of Days.	Below 20° (including below 10°). No. of Days.	32° or below.			Absolute.		32° or below.			Lowest Day.		40° and upwards. No. of Days.
						Date.			No. of Days.	Longest consecutive period and limiting dates. Days.	Date.		Date.	No. of Days.	Longest consecutive period and limiting dates. Days.	Date.		Date.	
IRELAND, N.—*Continued.*	°	°	°	°	°							°					°		
Londonderry	40·8	32·6	36·7	—3·9	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Mullaghmore	43·4	35·6	39·5	—2·4	26	J. 7	..	..	14	5	J. 5–9	55	D. 1	..	..	..	35	N. 27, J. 6	46
Belmullet	43·9	35·0	39·5	—4·5	26	N. 28, J. 7	..	..	20	4	D. 27–30 J. 5–8	53	N. 30, D. 2	..	..	..	35	J. 6	49
Markree Castle	40·9	29·8	35·4	—5·9	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Brookeborough	40·3	29·4	34·9	—5·0	14·8	D. 21, J. 7	..	7	33	15	D. 17–31	52·2	D. 1	1	1	D. 21	29·8	D. 21	35
Armagh	40·8	31·0	35·9	—4·0	15·9	D. 21	..	1	28	6	J. 5–10	53·9	D. 1	1	1	D. 21	29·5	D. 21	32
Donaghadee	43·3	35·6	39·5	—1·5	23	J. 7	..	..	17	5	J. 18–22	53	D. 1	..	..	..	35	J. 18 & 21	51
Edgeworthstown	39·6	29·8	34·7	—4·8	17	J. 7	..	3	40	8	D. 24–31	54	D. 1	3	2	D. 20 & 21	30.	N. 27, D. 21	31
IRELAND, S.																			
Dublin	42·3	34·6	38·5	—2·6	23·9	J. 7	..	..	18	4	D. 19–22	53·9	D. 1	0	..	..	32·9	D. 20	38
Parsonstown	41·2	28·8	35·0	—5·0	17	J. 7	..	3	45	14	J. 3–16	54	D. 1	2	1	J. 6, J. 9	31·6	J. 9	38
Kilkenny	41·5	29·8	35·7	—4·1	15	J. 7 & 8	..	3	41	11	J. 4–14	52	D. 1 & 3	1	1	D. 20	30	D. 20	39
Waterford	42·7	32·5	37·6	—4·4	17	J. 7	..	1	31	11	J. 5–15	51	D. 1	..	..	..	35	N. 27, D. 28 & 29	44
Roche's Point	45·1	35·2	40·2	—2·8	27	N. 27, J. 7	..	..	19	5	J. 4–8	51	D. 1, 2 & 11	..	..	..	35	D. 29	54
Valencia	46·7	36·1	41·4	—3·5	27	N. 27 & 28	..	..	13	4	N. 27–30	54	N. 30, D. 1	..	..	..	38	D. 29 & 30	57
Killarney	44·0	31·4	37·7	—5·7	16·8	J. 6	..	4	36	9	D. 23–31 J. 2–10	54·0	D. 1	0	..	..	33·5	D. 27	45
Foynes	42·5	32·2	37·4	—4·3	21·0	J. 6	..	..	31	12	D. 22–J. 2	56·8	D. 1	2	1	N. 27 & J. 6	31·8	J. 6	41

MEAN MAXIMUM TEMPERATURE—*Continued from p. 94.*

Lowest.

33°·5 at Greenwich.	33°·7 at Hillington.
33·8 ,, Rothamsted.	33·8 ,, Oxford.

at going outside of the Meteorological Office stations

33·3 at Kenley.

MEAN MINIMUM TEMPERATURE.

Highest.

38°·1 at Scilly	36°·2 at Sumburgh Head.
36·1 ,, Valencia.	

Lowest.

22°·3 at Cambridge.	22°·4 at Strathfield Turgiss.

But going outside of the Meteorological Office returns

21·4 at Beddington.	21·8 at Waddon.

Mr. Symons, in his *Meteorological Magazine*, gives the mean minima for several European Stations from December 13th to January 22nd, and completing this for a few stations for the period dealt with in this paper, we get:—

18°·6 at Brussels.	21°·1 at Paris.
32·7 at Biarritz.	38·9 at Rome.

The mean minimum at Biarritz being 0°·3 colder than at Ardrossan.

The *Absolute Minimum* occurred at different periods of the frost; it was only 27° at Sumburgh Head, and 25° at Stornoway, but it is more interesting to examine the region of the severe frost.

In England NE the coldest day was January 18th or 19th, and at Rounton the temperature fell to 0°·6 (the same temperature was also recorded at Stokesay on December 22nd, and is the lowest authentic reading during the frost).

In England N.W. the minimum occurred generally on December 20th, 22nd, or January 18th, but not in all places. The absolutely lowest reading was 5°·0 at Northwich on December 22nd.

In England E the minimum occurred generally on January 11th at the Northern stations, the lowest reading being 4°·1 at Somerleyton; whilst at the Southern stations the lowest reading occurred on December 22nd, and at Cambridge and Chelmsford the minimum was 4°.

In the Midland Counties the minimum temperature for the period was about equally divided between December 21st-23rd and January 18th or 19th. The absolutely lowest were 0°·6 at Stokesay, in Shropshire, on December 22nd and 1° at Stamford on January 18th.

In England S. the lowest readings occurred at very different periods of t' frost. In parts of Kent and Surrey as well as on the coast of Sussex a Hampshire the minimum occurred on November 28th or 29th, and at Wad' ' -- in the screen fell to 1°·0, whilst at Beddington it fell to 2 ' - fell to 12°; at Worthing and Rousdo

5°; at Margate, Hastings, and Southampton, to 16°; at Eastbourne and ortsmouth to 17°.

At some stations the readings were below 10° in the latter part of Decemer, and almost equally low readings occurred on January 10th-11th and 8th-19th, but the November readings in parts of Kent and Surrey were the ›west in the District for the whole period.

In England SW the minimum occurred on November 27th-29th, Decemer 31st, and January 19th. The South-coast stations had their minimum ı November, but in the greater part of the District the minimum occurred on anuary 19th. The absolutely lowest readings were 7° at Llandovery, 9°·5 t South Molton, and 10°·1 at Cullompton, on January 18th or 19th.

At Scilly and the Channel Islands the minimum occurred on November 8th-29th and January 17th-18th. The lowest reading was 12°·2 at Jersey n January 18th, which is within 0°·2 as low as the lowest reading at Greenrich during the frost.

In Ireland the lowest temperature occurred at very different dates at the everal stations, but at many of the coast stations it took place on November 7th or 28th. The absolutely lowest readings were 14°·8 at Brookeborough, nd 15° at Kilkenny.

The column for the number of days with the minimum 32° or below shows ıat at Addington Hills, near Croydon, frost occurred each night with but a single xception, and at both Cambridge and Reading there were only two excep. ons. At Sumburgh Head frost only occurred on 9 days, whereas at ›iarritz it occurred on 31 days, and at Rome on 9 days. At Brussels ıere was frost each day throughout the period.

At many places in England the frost was continuous night and day for 10 ays, but at coast stations in the North of Scotland it in no case lasted ıroughout the 24 hours.

The lowest day temperature shows that several different days were excep. onally cold. The absolutely lowest maximum day temperature was 21° at ›eading on December 14th.

It is comparatively easy to explain the great difference between the weather ver England and that in either Scotland or Ireland. During the whole eriod of the frost there was a large area of high barometric pressure situated ver Europe, which maintained an almost permanent position. The incoming isturbances from the Atlantic could not effect a passage into Europe, but eing fended off by the European anticyclone, their centres kept well ut in the Atlantic. Consequently both Ireland and Scotland felt the warming ıfluence of these disturbances, although the weather remained comparatively uiet, whilst England, and especially its eastern parts, was not at all affected y them.

The severity of the cold spell at the end of November is distinctly traceble to a long arm of easterly wind blowing directly over the British Islands rom off the cold Continent of Europe.

The very dry character of the weather over England during the frost is also ttributable to the fact that the European anticyclone embraced the southern

portion of the Kingdom, and although on two or three occasions there were some rather heavy falls of snow, the aggregate fall of snow and rain was but very trifling in comparison with the average.

Table II. is obtained from the 8 a.m. observations given in the *Daily Weather Report* of the Meteorological Office, and contains the means of the morning air temperatures for the several parts of the British Islands. The coast stations are too strongly represented for the general means to be absolutely correct, but the relative differences may be of value.

Fig. 3 shows the Greenwich shade temperatures for the whole period of the frost, also the average daily mean for the period derived from the observations of 60 years, 1814 to 1873. The temperatures used are for the civil day and will be found to differ slightly from those given in Table I.

This diagram (p. 109) shows that the mean temperature for each day was below the average with the single exception of January 13th. The marked absence of anything approaching warm days is also clearly shown.

On examination of the earth temperatures they show that the frost did not penetrate to the depth of 2 ft. below the surface of the ground in any part of England, but in many parts, especially in the south and east, the ground was frozen for several days at 1ft. below the surface, and at 6 ins. it was frozen for nearly a month. At Hodsock Priory, Worksop, the temperature at 1 ft. did not fall below 32°·8 throughout the period of the frost. The absolutely lowest temperature was reached on January 20th. The earth thermometer was continuously below 35° from December 21st to January 30th.

At Lowestoft the temperature at 4 ft. below the surface did not fall below 37°·9, which was registered quite at the end of the frost, and at 2 ft. deep it did not fall below 33°. At the depth of 1 ft. the thermometer stood at 31° on January 21st, but this was the only day throughout the period with the reading down to the freezing point.

At Berkhamsted the temperature at 2 ft. below the surface did not fall below 33°·4, the absolutely lowest temperature at this depth was on January 22nd, quite at the end of the frost. The soil at 1 ft. was frozen from January 11th to 28th, the lowest temperature was 30°·1 on January 19th and 20th.

Mr. Mawley writes:—"The soil in the kitchen garden, and also in a border in the flower garden is frozen to the depth of 8 ins. As I was surprised to find the frost had gone no deeper, I had a piece of the lawn exposed near where the earth thermometers are situated, and there the depth of frozen soil was 7 ins. As the lowest reading here was 30°·1 at 1 ft. and 33°·4 at 2 ft., it seems that it takes a lower temperature than 32° to freeze soil, at all events when moderately dry as it has lately been." The test was made by Mr. Mawley on January 22nd.

At Harestock, near Winchester, the temperature at 6 ft. below the surface did not fall below 43° during the period of the frost, and it was not below 46° during December. At 4 ft. the temperature fell to 39° at the end of the frost, and at 2 ft. to 33°·8, the lowest reading being registered on January 21st. At 1 ft. the soil was frozen from January 10th to 22nd, and the lowest temperature was 31°·1 on January 19th. At 6 ins. the soil was frozen from

TABLE II.—MEANS OF THE 8 A.M. TEMPERATURES PUBLISHED IN THE DAILY WEATHER REPORT, NOVEMBER 25TH, 1890, TO JANUARY 22ND, 1891.

Date.	Scotland.	Ireland.	England.	British Isles.
November 25....	38°	42°	36°	38°
„ 26....	35	36	32	33
„ 27....	27	31	29	29
„ 28....	30	31	29	30
„ 29....	33	33	29	31
„ 30....	43	46	31	37
December 1....	52	52	40	45
„ 2....	49	50	38	43
„ 3....	39	43	38	39
„ 4....	39	38	42	40
„ 5....	40	42	40	40
„ 6....	38	41	39	39
„ 7....	34	39	35	36
„ 8....	36	38	36	37
„ 9....	39	36	34	36
„ 10....	34	35	36	35
„ 11....	40	45	34	38
„ 12....	38	44	31	36
„ 13....	33	41	30	34
„ 14....	35	42	27	33
„ 15....	41	44	31	36
„ 16....	37	38	31	34
„ 17....	36	33	32	33
„ 18....	35	41	31	35
„ 19....	31	37	31	33
„ 20....	35	35	29	32
„ 21....	29	31	29	30
„ 22....	34	43	23	31
„ 23....	42	44	32	37
„ 24....	35	35	32	34
„ 25....	40	41	29	34
„ 26....	37	35	35	35
„ 27....	36	35	33	34
„ 28....	36	37	32	54
„ 29....	33	35	32	33
„ 30....	37	36	29	32
„ 31....	38	34	27	31
January 1....	39	41	36	38
„ 2....	38	39	32	35
„ 3....	37	39	33	35
„ 4....	37	39	38	38
„ 5....	33	34	31	32
„ 6....	31	32	28	30
„ 7....	29	29	25	27
„ 8....	34	38	28	32
„ 9....	33	37	32	34
„ 10....	33	34	27	30
„ 11....	44	43	28	35
„ 12....	49	41	34	39
„ 13...	44	40	39	40
„ 14....	36	41	36	37
„ 15....	36	39	32	35
„ 16....	36	44	35	38
„ 17....	33	39	27	31
„ 18....	32	35	22	27
„ 19....	35	38	23	30
„ 20....	43	46	38	41
„ 21....	30	36	34	34
„ 22....	32	40	37	37
Mean 59 days.	37	39	32	35
Days with mean temp. 32° or below	9	5	35	16
Lowest daily mean	27° Nov. 27	29° Jan. 7	22° Jan. 18	27° Jan. 7 & 18

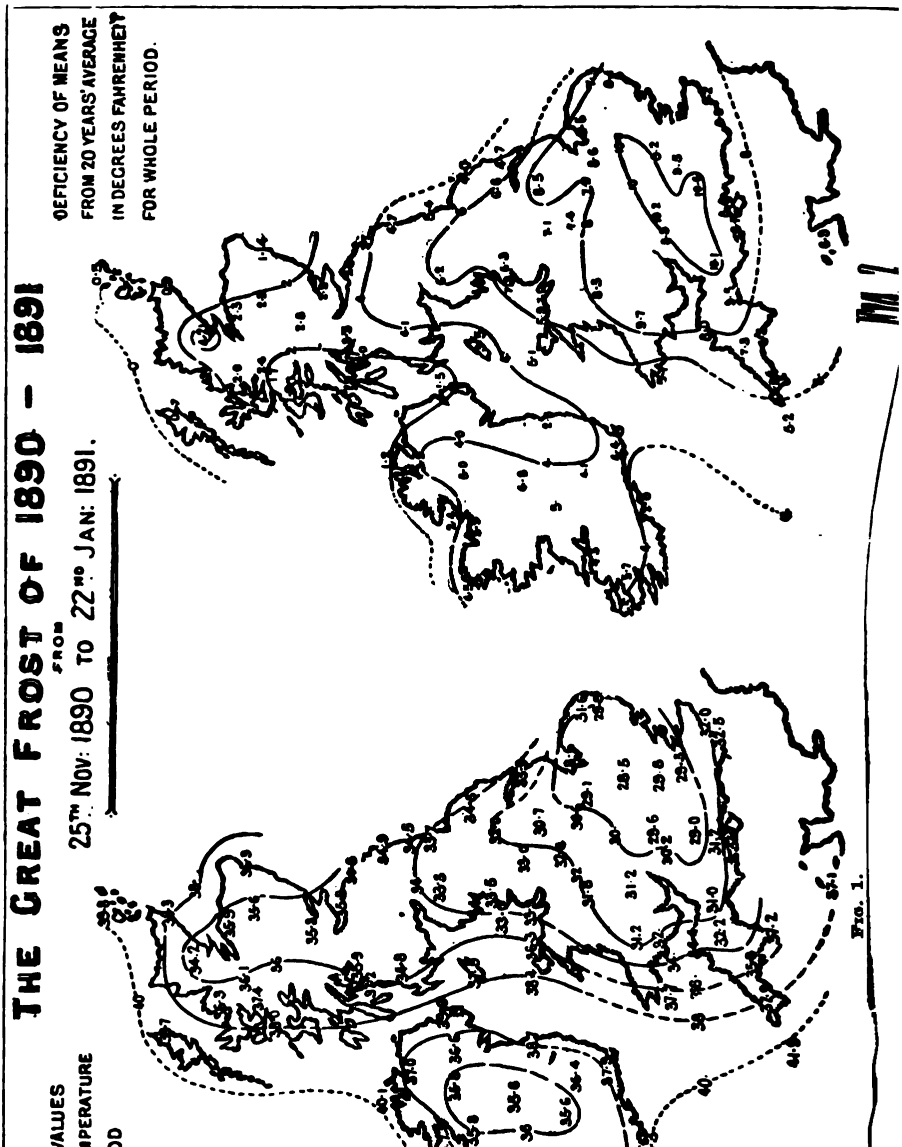

THE GREAT FROST OF 1890 - 1891
FROM
25TH NOV: 1890 TO 22ND JAN: 1891.
ISOTHERMS AND VALUES
SHOWING MEAN TEMPERATURE
FOR WHOLE PERIOD
DEFICIENCY OF MEANS
FROM 20 YEARS' AVERAGE
IN DEGREES FAHRENHEIT
FOR WHOLE PERIOD.

FIG. 1.

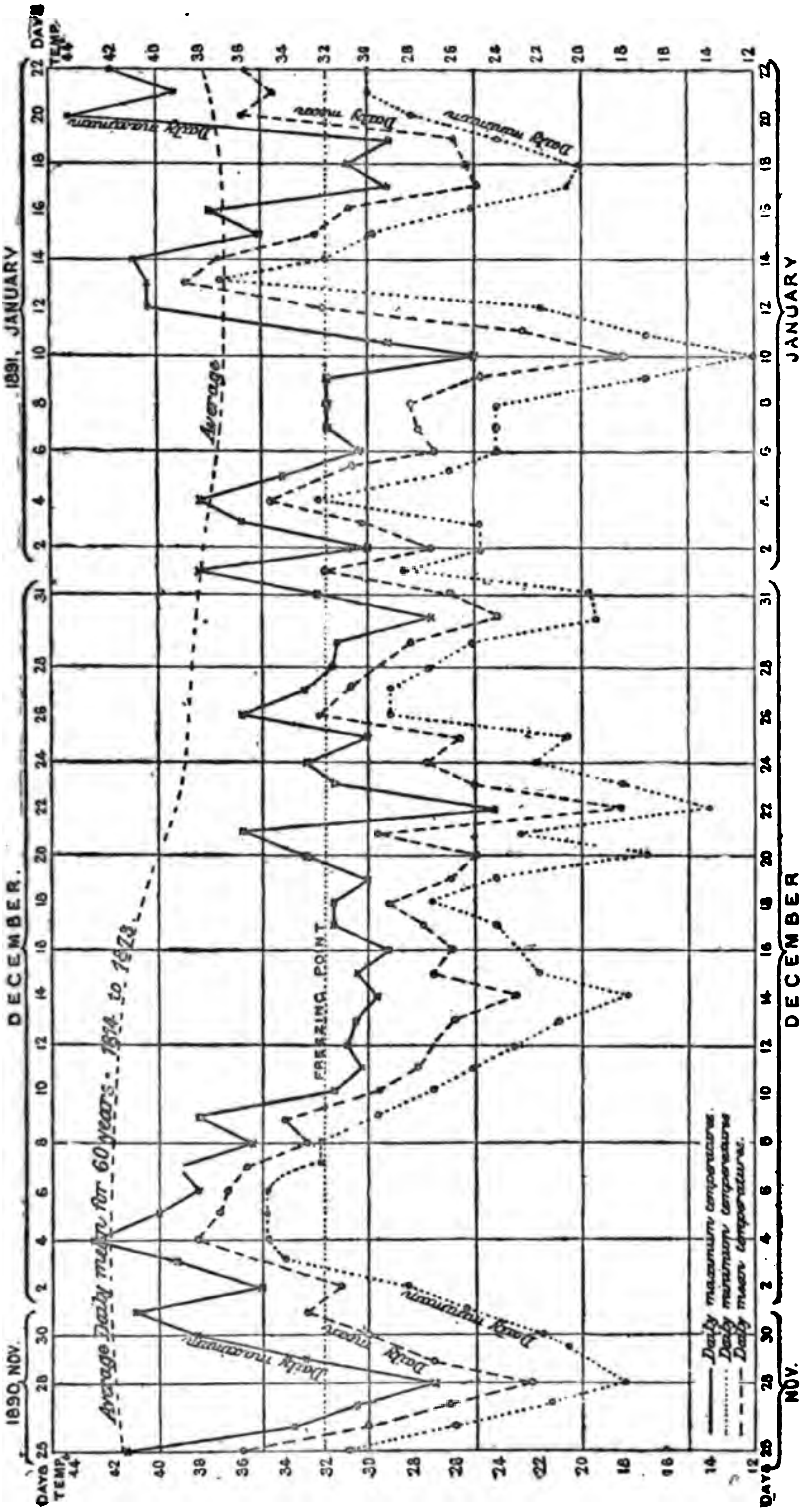

1890 NOV.
DECEMBER.
1891. JANUARY
NOV.
DECEMBER
JANUARY
DAYS
TEMP.
FREEZING POINT
Average Daily mean for 60 years: 1814 to 1873
Average
Daily maximum
Daily mean
Daily minimum
Daily maximum temperature.
Daily minimum temperature.
Daily mean temperature.

FIG. 3.

TABLE III.

SHOWING THE MEAN TEMPERATURE AND THE ANNUAL DEATH-RATE PER 1,000 OF THE TOTAL POPULATION FOR EACH WEEK IN THE THREE MONTHS NOVEMBER, DECEMBER 1890, AND JANUARY 1891, OBTAINED FROM THE REGISTRAR GENERAL'S WEEKLY RETURNS.

Weeks ending	November.				December.				January.				
	8.	15.	22.	29.	6.	13.	20.	27.	3.	10.	17.	24.	31.
	°	°	°	°	°	°	°	°	°	°	°	°	°
Mean temperature of all England..	45·0	43·2	48·7	35·9	37·3	33·0	29·8	30·4	31·5	30·2	33·2	34·3	43·4
Death rate in 28 Great Towns of England & Wales	20·8	21·1	21·3	19·0	21·5	21·3	25·1	27·8	28·7	28·1	27·3	25·1	22·3
Mean temperature at Greenwich ..	45·2	44·5	50·0	34·3	35·3	30·6	26·9	28·1	28·6	23·2	30·9	35·3	44·2
Death ra'es in London—all causes	20·5	20·2	20·2	18·0	20·4	21·1	26·0	26·3	29·7	29·1	29·2	25·7	22·1
Ages at death. Years under 1	393	392	369	296	362	354	414	389	459	397	417	401	370
1 to 5	283	257	308	266	296	304	384	333	313	358	289	297	262
5 to 20	109	109	112	100	100	109	101	102	120	121	104	78	87
20 to 40	222	239	226	207	205	210	257	251	236	298	296	333	206
40 to 60	331	296	283	277	317	319	419	412	511	488	595	450	390
60 to 80	318	343	350	300	372	391	515	602	729	705	659	615	471
89 & above	78	73	68	81	81	100	116	142	148	138	153	138	117
Deaths from Respiratory Organs	465	465	459	375	444	487	753	806	927	991	1018	845	636
Phthisis	153	174	184	151	189	161	203	187	182	183	216	182	136
Dis. of Circulatory System ..	141	139	134	130	167	157	200	189	219	220	220	194	156

These figures show the very marked increase in the death rate with persons whose ages are above 40 years, also the high rate of increase in the number of deaths from diseases of the respiratory organs. It is however seen that there is a falling off in the number of the deaths before the period of the frost has ended.

December 15th to January 26th, the lowest reading was 28°·6 on January 19th.

At Stowell, in Somerset, the soil was frozen at the depth of 1 ft. only on two days, January 19th and 20th, the lowest temperature being 31°·8. The temperature was however 34°, or below it, from December 30th to January 28th.

At Southampton the temperature 4 ft. below the surface reached its minimum after the termination of the frost, the lowest reading was 39°·4 from January 27th to 30th; in December it did not fall below 42°·6. At 2 ft. it fell to 36°·2 on the last day or two of the frost. At 1 ft. the lowest temperature was 33°·8 on January 19th and 21st. At 6 ins. deep the soil was 32° or below from January 7th to 25th, the lowest reading was 27°·5 on January 19th.

At Babbacombe, on the South Coast of Devon, the temperature at 1 ft. below the surface did not fall below 34°·5, which was reached on January 21st, whilst at 6 ins. the lowest temperature was 33°·1 on January 19th.

At Greenwich the mean temperature of the earth at 3 ft. below the surface was 38°·1 for the month of January, which is 4°·0 below the average for the previous 43 years, and lower than in any month during the same period, with

the exception of February 1855, when the mean was 36°·9. The earth at the depth of 1 in. below the surface was only frozen at noon on 15 days throughout the whole period of the frost.

The observations published in the Weekly Returns of the Registrar-General show that the temperature of the Thames water off Deptford, at 2 ft. below the surface, was continuously below 34° from December 23rd to January 23rd, a period of 32 days, while the river was blocked with ice during the greater part of the time.

The records of sea surface temperature received by the Meteorological Office from light-ships, &c. round the coasts of the British Islands show that, in November the mean sea temperature was in good agreement with the average conditions. In the English Channel the mean was about 53°, whilst it was about 48° on the West coast of Ireland and 47° on the East coast of England. In December the sea temperature was colder than the average, but the difference was very irregular. In the Hebrides the deficiency on the average was about 3°, on the West coast of Ireland about 2° or 3°, whilst in the South of Ireland the water was but very slightly colder than usual. In the English Channel the deficiency ranged from about 5° on the coast of Devon to only 1° in the Eastern half of the Channel. On the East coast of England the sea was colder by 2° or 3°, but that on the East coast of Scotland was slightly warmer than usual. A comparison of the air and sea temperature on the coasts of the British Isles shows that on the coast of Sussex the sea was 14° warmer than the air, on the coast of Norfolk 12° warmer, on the coast of Yorkshire and the North-east of England 6° warmer, off the Northeast of Scotland 8° warmer, in the Shetlands 3° warmer, in the Hebrides the temperature of the air and sea were the same, on the West coast of Ireland the sea was from 3° to 5° warmer than the air, in Cardigan Bay it was 13° warmer, and at Scilly 9° warmer.

A record of the sea temperature at Eastbourne is given by Mr. Sheward, the observation being made at the Pier Head each day at 8.30 a.m. This temperature is, however, very different from that given on board the *Royal Sovereign* Light Ship, but the conditions are not at all similar. At Eastbourne the sea is shallow, and the beach would naturally be cold under the influence of the low air temperature. The *Royal Sovereign* is in comparatively deep water, and at about six miles distant from the shore. At Eastbourne the mean sea temperature in December was 37°·8 ; there was no day with the temperature above 42°, and on 7 days it was 35° or below ; whilst at the *Royal Sovereign* the mean for December was 46°·3, and the temperature was not once below 42°. At Eastbourne the mean sea temperature in January was 34°·5, at no time did the thermometer indicate a higher reading than 38°, and 36° was not exceeded until the 28th ; whilst on the 9th the temperature was 31°, which is the lowest reading observed during 7 years by Mr. Sheward. On the morning of the 11th the sea temperature at the Pier Head was 32°, and the incoming edge of the sea is reported to have been fringed with ice. At the *Royal Sovereign*, in January, the mean temperature of the water at the depth of 1 foot was 40°, and there were only 3 days during the

month with the reading below 36°, although at sunrise on January 18th and 19th the thermometer registered 31°.

The *Pilot Chart* of the North Atlantic Ocean for February, published by the United States' Hydrographic Office, gives some interesting accounts of obstruction caused to navigation owing to rivers and ports being blockaded by ice. The following is a brief abstract of the reports :—

HAMBURG, *January 8th.*—Since Christmas the Island of Heligoland has been cut off from all communication with the mainland, and great masses of ice are floating in the North Sea, off the mouth of the Elbe.

STETTIN, *January 9th.*—There is 15-inch ice in the Haff; in places it is piled up several feet high, and firmly frozen together.

KIEL, *January 19th.*—The Baltic, as far as it can be seen, is covered with ice.

TOULON, *January 19th.*—The harbour is frozen over for the first time on record.

BORDEAUX, *January 19th.*—A large number of vessels are ice-bound, and many vessels have gone down the river to avoid being frozen in.

LONDON, *January 19th.*—The ice floating on the Thames between the Bridge and Tower is so packed that all movements of vessels have entirely ceased.

LISBON, *January 20th.*—The River Tagus is frozen over. The Ebro is covered with 19 ins. of ice, the first since 1829.

The following statement with regard to the thickness of the ice and days of skating was kindly furnished by Colonel Wheatley, R.E., of the Office of Works :—

In Regent's Park skating commenced on December 18th, 1890, and continued till January 24th, 1891, lasting 43 days. 344,000 persons (approximately) frequented the ice during this period. On November 28th the ice was ¾ of an inch thick, and attained 1¾ in. at the end of the month, the greatest thickness of the ice was 9¼ ins. on January 20th. On January 26th the thickness varied from 6 to 7¼ ins., and the ice was flooded with water from thaw, which was very rapid, as on the 31st all ice had disappeared even from the creeks.

In St. James's Park skating commenced December 15th, 1890, and continued without interruption till January 24th, 1891, a period of 41 days. The ice was 1 inch thick at the end of November, and attained the thickness of 8¾ ins. on January 20th.

In Hyde Park skating commenced on December 25th, when the thickness of the ice varied from 2⅞ to 3¾ ins., and continued till January 24th ; the greatest thickness of the ice was 8 ins. on January 22nd and 23rd.

In Regent's Park the previous records show that in 1881 skating commenced on January 13th and continued till the 27th, a period of 15 days.

In St. James's Park in the Seasons of 1879-80, skating was allowed December 3rd to 12th, 17th to 19th, 24th to 27th, January 26th to February 2nd, 4th, and 5th. In the Season 1880-1 skating was allowed January 15th to 27th. There was no ice in Season 1881-2, 1882-3, 1883-4, and 1884-5. In the Season 1885-6 there was no skating, but the ice was measured on most days from December 11th to March 17th, the greatest thickness of the ice was 3 ins. In the Season 1886-7 there was skating on December 22nd and 23rd, and January 1st to 11th. In the Season 1887-8 ice was measured frequently after December 27th, whilst skating was allowed from February 29th to March 6th. In the Season 1888-9 ice was measured in January, February, and March, the greatest thickness was 2¼ ins. on February 13th, but no skating was allowed. In the Season 1889-90 ice was measured in December, January, and March, but no skating was allowed.

In Hyde Park in the Season of 1879·80 skating was allowed on December 8th to 13th, 17th to 19th, 24th to 28th, January 27th to February 2nd, and 5th, the greatest thickness of the ice was 5¼ ins, on December 27th. In the Season 1880-1 skating was allowed January 18th to 27th, and the ice attained the thickness of 6 ins. There was no ice in Seasons 1881-2, 1882-3, 1883-4, and 1884-5. In the Season 1885-6 ice was measured frequently from December 11th to March

TABLE IV.

NUMBER OF DAYS WITH THE MINIMUM TEMPERATURE 32° AND BELOW, AND BELOW 20°, AT THE ROYAL OBSERVATORY, GREENWICH, FOR THE SIX WINTER MONTHS, FROM 1841 TO 1891.

Winters.	October.		Nov.		Dec.		January.		February.		March.		Winter 6 Months.	
	32° or below.	Below 20°.	32° or below.	Below 20°.	32° or below.	Below 20°.	32° or below.	Below 20°.	32° or below.	Below 20°.	32° or below.	Below 20°.	32° or below.	Below 20°.
1841–42	..	..	9	..	12	..	25	..	9	..	3	..	58	..
1842–43	6	..	1	..	2	..	11	..	12	..	9	..	41	..
1843–44	5	..	6	..	2	..	9	1	17	..	8	..	47	1
1844–45	1	..	2	..	20	..	12	..	19	2	18	2	72	4
1845–46	1	..	5	..	7	..	4	..	6	..	6	..	29	..
1846–47	..	..	3	..	24	3	18	..	18	5	13	1	76	9
1847–48	..	..	4	..	6	..	23	1	7	..	5	..	45	1
1848–49	..	..	9	..	5	..	13	1	7	..	6	..	40	1
1849–50	1	..	6	..	14	1	24	..	3	..	13	..	61	1
1850–51	1	..	3	..	6	..	3	..	9	..	2	..	24	..
1851–52	..	..	16	..	8	..	5	..	7	..	15	..	51	..
1852–53	1	..	..	..	1	..	3	..	21	..	18	..	44	..
1853–54	1	..	7	..	20	1	8	2	10	..	10	..	56	3
1854–55	1	..	10	..	8	..	20	2	22	10	16	..	77	12
1855–56	..	..	5	..	3	..	10	..	6	..	13	..	37	..
1856–57	2	..	9	1	13	1	19	..	12	..	9	..	64	2
1857–58	..	..	3	..	4	..	17	..	22	..	14	..	60	..
1858–59	..	..	14	..	4	..	6	..	6	..	2	..	32	..
1859–60	5	..	12	..	14	3	8	..	18	..	9	..	66	3
1860–61	..	..	4	..	13	3	22	5	5	..	2	..	46	8
1861–62	..	..	8	..	7	..	11	..	5	..	4	..	35	..
1862–63	1	..	10	..	..	..	4	..	8	..	8	..	31	..
1863–64	..	..	5	..	5	..	13	2	17	..	10	..	50	2
1864–65	..	..	7	..	12	2	17	3	14	1	17	..	67	6
1865–66	..	..	3	..	2	..	6	..	10	..	11	..	32	..
1866–67	1	..	8	..	8	..	18	7	..	..	17	..	52	7
1867–68	3	..	4	..	20	..	17	..	5	..	5	..	54	..
1868–69	2	..	10	..	1	..	8	..	2	..	16	..	39	..
1869–70	4	..	8	..	11	..	12	1	15	1	13	..	63	2
1870–71	..	..	9	..	19	5	20	2	5	..	7	..	60	7
1871–72	1	..	15	..	10	1	2	..	..	..	10	..	38	1
1872–73	1	..	..	..	3	..	8	..	18	..	16	..	46	..
1873–74	6	..	3	..	8	..	6	..	15	..	9	..	47	..
1874–75	..	..	10	..	22	3	3	1	21	..	14	..	70	4
1875–76	..	..	6	..	13	..	19	2	9	..	10	..	57	2
1876–77	..	..	5	..	4	..	7	..	3	..	12	..	31	..
1877–78	4	..	2	..	9	..	11	..	5	..	11	..	42	..
1878–79	1	..	6	..	21	3	26	1	12	..	11	..	77	4
1879–80	..	..	14	..	24	4	23	5	6	..	4	..	71	9
1880–81	3	..	10	..	6	..	19	10	11	..	11	..	60	10
1881–82	5	..	1	..	8	..	8	..	6	..	4	..	32	..
1882–83	1	..	4	..	10	..	4	..	3	..	22	..	44	..
1883–84	..	..	4	..	4	..	2	..	5	..	4	..	19	..
1884–85	..	..	7	..	3	..	20	..	4	..	13	..	47	..
1885–86	1	..	6	..	11	..	18	1	17	..	18	..	71	1
1886–87	..	..	5	..	17	3	19	3	17	1	18	..	76	7
1887–88	6	..	6	..	16	..	14	..	20	3	18	..	80	3
1888–89	7	..	..	..	11	..	12	1	18	2	12	1	60	4
1889–90	..	..	6	..	15	..	3	..	11	..	7	1	42	1
1890–91	2	..	6	1	25	6	20	3	14	..	9	..	76	10

TABLE V.

PROLONGED FROSTS OF THE LAST CENTURY, FROM OBSERVATIONS MADE IN LONDON AND ITS VICINITY.

Date.	Days duration.	Temperature.				Days.					
		Mean Max.	Mean Min.	Mean of Max. and Min.	Absolute Min.	Min. below 20°	Continuous frost.	Daily Mean 32° or below.	Max. 32° or below.	Max. 40° or above.	Absolute Max.
		°	°	°	°						°
1788–9 Nov. 26 to Jan. 13[1] ..	49	31·3	27·5	29·4	17·5	4	12	33	30	3	46
1794–5 Dec. 18 to Feb. 7 ..	52	31·9	25·3	28·6	7	11	12	35	23	3	46
1813–4 Dec. 26 to Feb. 5 ..	42	33·0	21·5	27·3	8	16	11	32	20	5	41
1838 Jan. 5 to Feb. 23 ..	50	32·9	24·9	28·9	—4·0	9	13	31	19	5	50
1855 Jan. 10 to Feb. 25 ..	47	34·8	24·5	29·7	11·1	12	4	31	15	7	48
1860–1 Dec. 15 to Jan. 19 ..	36	34·9	24·8	29·9	8·0	8	3	26	9	4	47
1879 Nov. 14 to Dec. 27 ..	44	37·2	24·7	31·0	13·7	4	2	22	6	12	55
1881 Jan. 7 to 26........	20	31·8	22·1	27·0	12·7	10	9	14	12	1	41
1890–1 Nov. 25 to Jan. 22 ..	59	33·5	25·0	39·3	12·0	10	10	41	27	9	44

18th; it attained the thickness from 3¼ to 5 ins. on March 10th, but skating was not allowed, the "Public being warned off the ice by notice" during the whole period of frost. In the Season 1886-7 skating was allowed on January 2nd and 3rd, the greatest thickness of the ice was 5 ins. In the Season 1887-8 there was no skating, but ice was frequently measured from December 28th to March 6th, the greatest thickness of the ice was, however, 2¼ ins. In the Season 1888-9 ice was measured occasionally from January 7th to March 7th, but the thickness never exceeded ½ in., and it is needless to say no skating was permitted. In the season 1889-90 ice was measured frequently from December 2nd to March 6th, but there was no skating, and the greatest thickness of ice was 1½ in.

The return showing the state of the ice, &c. at Regent's Park contains the following, remark, the report being dated February 6th, 1891:—"It is too early to observe the full effects of the late frost on trees and shrubs; injury has been done, hollies and ivies are in many cases losing their leaves, privets and many other hardy shrubs are as if scorched by fire, hoar frosts have been dense, and must have affected the limbs of trees that are weakened by canker or other disease. Owing to the plentiful covering of snow during the sharpest weather, herbaceous vegetation has not suffered to any great extent.

"In contrast to the present winter, I may mention that last year the winter aconite was coming into flower on January 12th; by the 17th the primroses were blooming, and auriculas pushing up their trusses. At this season I do not observe a sign of movement from the winter aconite, and other plants, as the snowdrop and crocus, are still below the turf."

I have to thank the Meteorological Council for so kindly allowing me free use of information in the Meteorological Office, also the Council of the Royal Meteorological Society for the use of its valuable returns and the material assistance afforded in the compilation of the paper. I would also thank Mr. Symons for the large amount of material with which he has supplied me, and others who have so cordially assisted by the prompt supply of observations.

[1] The frost of 1788–9 has been included, as it occurred but little more than 100 years ago, the temperatures however are not from self-registering thermometers, but the observations used as the maximum were made at 2 p.m., and those for the minimum at 8 a.m. each day. The observations for all the other periods are from self-registering thermometers.

It may be interesting to mention that nearly all the prolonged frosts of the last century were followed by a fairly dry spring and summer, but the accompanying weather was by no means always hot.

DISCUSSION.

Dr. WILLIAMS said that this paper contained all the important facts relating to the great frost which had been recently experienced, and afforded abundant material for the formation of theories as to the cause of the prolonged cold weather. He had hoped that Mr. Harding would have explained more fully the cause of the comparatively warm weather which prevailed on the east coast of Scotland during this period. Travellers from the North of Scotland stated that no severe weather was experienced until they reached York, and the London district seems to have been visited with special severity. The effect of the prolonged cold on health was very unfavourable, especially in the case of the middle aged and elderly people, capillary bronchitis and pneumonia being induced, which often proved fatal in a few days.

Dr. BUCHAN said the high temperatures experienced at the sea-coast stations in Scotland were due to the fact that these places were situated on the western side of the extraordinary anticyclone which prevailed over the continent of Europe. In the Orkney and Shetland Islands the temperature during December was from $0^{\circ}\cdot5$ to $0^{\circ}\cdot8$ above the average, the wind in the Orkney Islands was from the South-east, and in the Shetland Islands the direction was South-south-west. In the north of Norway (which was situated on the northern side of the anticyclonic area) the temperature was from 5° to 7° above the average. To the southward the conditions which gave rise to low temperature prevailed, and they extended as far as Algeria. The intensity of the cold largely depended upon whether the polar winds, which were experienced, passed over a large extent of land or sea. The fact that no very intense cold was experienced over England during the period of the frost was due to the absence of bright sunshine, and, in consequence, to there being very little radiation. In Edinburgh only four or five hours of sunshine were recorded during December, and in London the amount was considerably less if any had been noted. The whole question of winter weather in the British Islands depended upon whether the cyclones occurring in Western Europe passed to the north or south of the British Islands. If we could forecast the course of winter cyclones, we could then forecast the character of our winter weather.

Mr. SCOTT remarked that no sunshine was registered by the recorder on the roof of the Meteorological Office during the month of December, and that only five minutes' sunshine was registered at Bunhill Row.

Mr. SYMONS called attention to the close resemblance which there was between Mr. Harding's chart of mean temperature over Ireland and that given by Prof. Hennessy in his paper on temperature.[1] He thought that a summary of Dr. Hellmann's recent paper on the depth of snow over Germany during the winter might be included in Mr. Harding's account of the frost. He also referred to the practical value of earth temperature observations in determining to what depth frost would penetrate the earth, more especially in connection with the question of what depth below the surface water mains and service pipes should be laid in order to be secure from the effects of frost. He also gave an account of the mischief wrought in the Camden Road through the Tramway Company using salt for thawing the snow on the tramway lines, and not removing the resultant slush, which, of course, was some 30° colder than the snow before the addition of the salt. He considered that one of the most remarkable temperatures recorded in the frost was the reading of $12^{\circ}\cdot2$ at Jersey.

Dr. MARCET stated that during the late frost the harbour at Geneva had been completely frozen over, and used as a promenade by the inhabitants of the city. He read the following extract from the *Journal de Genève*, of January 18th last, giving an interesting account of the past cold winters:—

"In 762 the cold was so great that the lake was completely frozen; this cold weather was followed by so great a heat that the plague broke out and several thousand people died.

"In 805 the cold was so intense that carriages crossed the lake on the ice from Thonon to Nyon.

"In 1196 the weather was so cold that all the trees and vines were killed; a hot season followed, and the heat was fatal to many people.

[1] *Proc. R. Irish Academy.* Vol. VI.

"In 1378 the cold was so great that all the trees and vines were dried up (séchés); a famine which lasted two years followed this cold period.

"In 1573 there was so cold a winter that several people were found dead in their own houses, the intensity of the cold put an end to the plague which prevailed at the time. In the month of March the River Arve rose so high from the melting of the snow that it arrested the current of the Rhone, so that the 'Rues-Basses and Plainpalais' (in the town) were under water.

"According to M. Forel, the distinguished Swiss Physicist, the Lake of Geneva was frozen in the years 1570, 1681, 1685, 1709, 1785 and 1788. Within the present century the harbour was frozen in 1810, 1820, 1830, 1854, 1880, and 1891."

Dr. Tripe inquired how it was that at the present time, with an anticyclone as high as that which prevailed during the recent frost, dry and mild weather was being experienced. He thought that the falling-off in the death-rate of middle-aged and elderly people before the cold weather ended was due to the fact that the severe weather had already lasted a sufficiently long time to kill all such persons as were specially susceptible to cold.

Mr. Harries, referring to the suggestion of a probable connection between the long frost and the conditions which brought such an abnormal quantity of ice into the Atlantic last year, said that an examination of the European Daily Weather Reports showed the cold weather to have set in on the evening of November 16th over North-Eastern Russia. The morning temperature at Archangel was 36°, barometer 29·9 ins. By the evening the barometer had risen, from the eastward, to 30·3 ins., and next morning the temperature was —11°. Henceforward the weather under the influence of the Siberian anticyclone was very cold, but over Western Europe an anticyclone which had come from the Atlantic was accompanied by warm weather. From November 19th low pressure systems travelled between these anticyclones in a south-easterly direction from Iceland to Hungary, and on the 24th the high pressure and low temperature in the north of Europe were spreading in a south-westerly direction over Scandinavia. The East winds of this system covered the British Isles on the 25th, and next day nearly the whole of Europe was affected. The origin of our severe weather, therefore, was to be sought for in the far East—over Siberia—and not in the West. (The Atlantic ice had been set free in Northern Greenland as long ago as the summer of 1889). During the two months under discussion we were visited by several cyclonic and anticyclonic areas, but the former were not all mild, neither were the latter all cold. It follows from this that we must study our weather systems, not so much according to the high or low barometer, as to the special characteristics of individual areas, these depending upon the source or sources from which each derives its supply of air, the East wind of one anticyclone bringing with it a sharp frost, and that of another anticyclone a decided thaw.

Mr. Southall said that as Mr. Harding had referred to the thickness of ice, it might be of interest to state that in 1739-40 the ice in St. James's Park attained the thickness of 10½ inches. On the River Wye, in January 1795, the ice was a little over 1 foot thick, and during the recent frost it varied from 10 to 16 inches. In the neighbourhood of Ross the effect of the late frost on vegetation was not nearly so injurious as in 1838, 1861, or even 1881.

Mr. Rostron said that in the neighbourhood of Beddington more inconvenience was experienced from the freezing of water pipes after the thaw had commenced than before. On the second morning of the thaw he found the rain in the receiver of his rain gauge frozen into a solid piece of ice, a circumstance which had not taken place during the whole of his previous observations of 10 years. The injury to plants in his neighbourhood was most dreadful; even the hardiest evergreens had suffered severely, and he believed that it would be found when spring time came that the damage was even greater than at present it appeared to be. One feature of the frost was the great contrast between the temperature of the north of England and of Scotland and that of the south of England. He was at first led to suppose that this feature in long and severe frosts was unique; but from some records given by Dr. Derham in the *Gentleman's Magazine*, Vol. 84, Part 1, p. 142, he had found that in 1708-9 there was a similar contrast. Another prominent fact in connection with the recent frost was that the minimum on particular days occurred early in the evening. The

very low reading of 2°·6 registered at Beddington on November 28th occurred at about 5 p.m. He was disposed to accept the Somerset House values quoted by Mr. Harding with some reserve. He had compared them with some apparently reliable observations made at 8 a.m., noon, and 11 p.m. by Cary, an optician, in the Strand, and published in the *Gentleman's Magazine*, and was inclined to think that the Somerset House temperatures were too low.

Dr. Buchan pointed out that in studying anticyclonic systems it was not sufficient to consider surface winds only, as upper currents played a very important part in their production. The anticyclone which at present was over the British Isles had come from the Atlantic.

Mr. C. Harding, in reply, said that there was little doubt that we must have a much better knowledge of the movements of cyclones and anticyclones before we could hope to make any great advance in meteorology. During the anticyclone which prevailed in January last the barometer in Ireland attained probably the highest reading on record. This high pressure area came from Europe, and from a study of ships' logs he had found that when in about 30° west Longitude the barometer registered a pressure exceeding 31 ins. The temperatures recorded during an anticyclone depended upon where the supply of air was drawn from; and in the case of November 28th and 29th the air was drawn from Northern Europe. In the case of the present anticyclone the conditions were different, the high pressure area being situated immediately over England, and its area being considerably less than in the case of the January anticyclone. He believed the Somerset House values were quite reliable, as there was good evidence that the observations were carefully made.

PROCEEDINGS AT THE MEETINGS OF THE SOCIETY.

January 21st, 1891.

Ordinary Meeting.

W. H. Dines, B.A., Vice-President, in the Chair.

John Herbert Wilson, 6 West Park, Harrogate, was balloted for and duly elected a Fellow of the Society.

The following Papers were read :—

"Note on a Peculiar Development of Cirrus Cloud observed in Southern Switzerland." By Robert H. Scott, M.A., F.R.S. (p. 78.)

"Some Remarks on Dew." By Col. W. F. Badgley, F.R.Met.Soc. (p. 80).

January 21st, 1891.

Annual General Meeting.

W. H. Dines, B.A., Vice-President, in the Chair.

Mr. F. B. Edmonds and Mr. R. W. Munro were appointed Scrutineers of the Ballot for Officers and Council.

Dr. Tripe read the Report of the Council and the Balance Sheet for the past year. (p. 47.)

It was proposed by the CHAIRMAN, seconded by Dr. TRIPE, and resolved :—"That the Report of the Council be received and adopted, and printed in the *Quarterly Journal.*"

It was proposed by Dr. MARCET, seconded by the Hon. F. A. R. RUSSELL, and resolved :—"That the thanks of the Royal Meteorological Society be communicated to the President and Council of the Institution of Civil Engineers for having granted the Society free permission to hold its Meetings in the rooms of the Institution."

It was proposed by Mr. CHATTERTON, seconded by Mr. C. HARDING, and resolved :—"That the thanks of the Society be given to the President for his services during the past year."

It was proposed by Mr. M. JACKSON, seconded by Mr. MILLER, and resolved :—"That the thanks of the Society be given to the Officers and other Members of the Council for their services during the past year."

It was proposed by Mr. HARRIES, seconded by Mr. T. W. BAKER, and resolved:—"That the thanks of the Society be given to the Standing Committees, and to the Auditors ; and that the Committees be requested to continue their duties till the next Council Meeting."

The Scrutineers declared the following gentlemen to be the Officers and Council for the ensuing year, viz.:—

President.

BALDWIN LATHAM, M.Inst.C.E., F.G.S.

Vice-Presidents.

ARTHUR BREWIN.
CAPT. JOHN PEARSE MACLEAR, R.N., F.R.G.S.
WILLIAM MARCET, M.D., F.R.S., F.C.S.
CHARLES THEODORE WILLIAMS, M.A., M.D., F.R.C.P.

Treasurer.

HENRY PERIGAL, F.R.A.S., F.R.M.S.

Trustees.

HON. FRANCIS ALBERT ROLLO RUSSELL, M.A.
STEPHEN WILLIAM SILVER, F.R.G.S.

Secretaries.

GEORGE JAMES SYMONS, F.R.S.
JOHN WILLIAM TRIPE, M.D., M.R.C.P.Ed.

Foreign Secretary.

ROBERT HENRY SCOTT, M.A., F.R.S., F.G.S

Council.

FRANCIS CAMPBELL BAYARD, LL.M.
HENRY FRANCIS BLANFORD, F.R.S., F.G.S.
GEORGE CHATTERTON, M.A., M.Inst.C.E.
ARTHUR WILLIAM CLAYDEN, M.A., F.G.S.
WILLIAM HENRY DINES, B.A.
WILLIAM ELLIS, F.R.A.S.
CHARLES HARDING.
RICHARD INWARDS, F.R.A.S.
HENRY JOHN MARTEN, M.Inst.C.E.

EDWARD MAWLEY, F.R.H.S.
HENRY SOUTHALL.
WILLIAM BLOMEFIELD TRIPP, M.Inst.C.E.

FEBRUARY 18th, 1891.

Ordinary Meeting.

C. T. WILLIAMS, M.A., M.D., Vice-President, in the Chair.

CHARLES LEWIS BROOK, B.A., Harewood Lodge, Meltham, Huddersfield;
CHARLES EUGENE DE RANCE, F.G.S., F.R.G.S., Alderley Edge, Manchester;
JOSEPH EDEN, Assoc.M.Inst.C.E., Glenae House, Workington;
JAMES CHARLES MUNDELL, Moor Park, Rickmansworth; and
JAMES SIDEBOTTOM. J.P., Millbrook, Hollingworth, near Manchester;
were balloted for and duly elected Fellows of the Society.

The following Papers were read :—

"THE GREAT FROST OF 1890-1891." BY CHARLES HARDING, F.R.Met.Soc. (p. 93.)

"THE PROBLEM OF PROBABLE ERROR AS APPLIED TO METEOROLOGY." BY THOMAS WILLIAM BACKHOUSE. (p. 87.)

CORRESPONDENCE AND NOTES.

METEOROLOGICAL NOTES TAKEN ON THE SOUTH-EAST COAST OF MADAGASCAR, August 1889 to July 1890. By the Rev. GEORGE A. SHAW.

FARAFANGANA, or Ambàhy, one of the few ports on the east coast south of Mànanjàra, is situated in S. Lat. 22° 49 and E. Long. 47° 58′. It is enclosed on two sides by rivers of considerable volume which join to form a large lagoon between the town and the sea, and separated from the sea by a small bank of sand, which is constantly shifting, according to the relative strength of the two rivers and the force of the waves that break outside. Hence the opening to the sea is at one time in one place, at another time this is filled with sand, and the rivers break through at a spot which may be half a mile distant from the previous opening. At times each river forces a passage for itself in a line with the lower part of its course, leaving the bank of sand between as the eastern boundary of the lagoon. These openings, however, are always shallow, impeded with rocks and sand bars upon which the sea breaks with considerable violence. Close in-shore the southern half of the equatorial Indian Ocean current runs towards the south, at times with great rapidity. This extends to about 60 miles to the east, and naturally has its influence both on the climate and the wind, the latter blowing for days from the North or North-east, while at over 60 miles from shore only Southerly winds have been met.

On the west of the town are one or two swamps of sufficient extent to affect somewhat the climate of the place, and this factor, taken in conjunction with the large extent of forest immediately adjoining and extending towards the west, materially absorb, by the rapid evaporation during the night, the heat accumulated during the day. More especially so, as a land breeze blows with few exceptions every night throughout the year, springing up soon after sunset and continuing until 9 or 10 o'clock a.m. The exceptions depend entirely upon the strength of the wind during the day, especially if it is a Southerly wind, which often continues to blow throughout the night from the same point.

The observations from August 1889 to July 1890 have been taken in accordance with the instructions issued by the Royal Meteorological Society, with the exception of the barometer, an aneroid having been used instead of the usual standard barometer. The dry bulb, the wet bulb, and the maximum and minimum thermometers are in a Stevenson screen which is 4 ft. above the ground

covered with grass ; the black bulb thermometer *in vacuo* has the same elevation ; the minimum thermometer for terrestrial radiation is placed over short grass with the bulb just touching the tips of the blades.

Another variation from the Royal Meteorological Society's instructions is in the time of the second observation, which has been taken at 3 p.m. instead of 9 p.m., because both at 9 a.m. and 9 p.m. the land breeze is often blowing, and unless a third observation is added or the later time altered, the main characteristics of the day are missed.

The barometer has ranged from 29·94 ins. on March 3rd to 30·67 ins. on August 21st, 1889. The barometer stood highest during the previous August of any month in that year.

The greatest heat in the shade in a clear current of wind was 94° on January 7th. Three times in the same month 93° was registered, and ten times during the year the mercury stood at 92°. The greatest heat of the direct rays of the sun, as tested by the black bulb thermometer *in vacuo*, was registered on January 7th, when the mercury stood at 164°.

The lowest minimum of the air 4 ft. from the ground was noted on November 7th, when after a drizzling afternoon the thermometer during the night fell to 50°.

The lowest record of intensity of terrestrial radiation was on July 30th, when 40° was registered.

Rain fell on 181 days during the year ; the greatest amount in any single day of 24 hours fell on January 30th, when 6·73 ins. was measured.

The total rainfall for each month has been as under :—

		Ins.			Ins.
1889	August	13·70	1890	February	25·14
„	September	3·60	„	March	24·60
„	October	4·59	„	April	6·31
„	November	1·50	„	May	9·60
„	December	11·96	„	June	13·37
1890	January	24·00	„	July	6·97

making a total of 145·34 ins. for the year.

The wind, at time of observation, viz. either 9 a.m. or 3 p.m. or both, was blowing:—

Between	North	and	East	including	North	on	158 days.
„	East	„	South	„	East	„	134 „
„	South	„	West	„	South	„	40 „
„	West	„	North	„	West	„	62 „

The great majority of the Westerly winds were registered at the 9 a.m. observation and represented the land breeze.

The following are the averages for each month :—

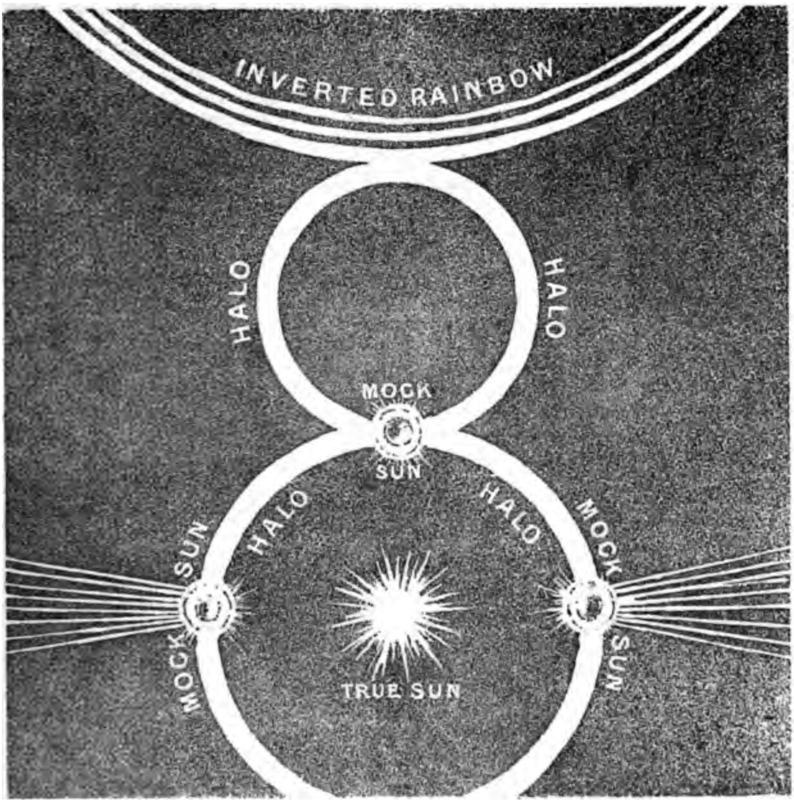
Month.	At 9 a.m.					At 3 p.m.							
	Barometer.	Thermometer. Dry Bulb.	Thermometer. Wet Bulb.	Force of Wind. 0–12.	Amount of Cloud. 0–10.	Barometer.	Thermometer. Dry Bulb.	Thermometer. Wet Bulb.	Force of Wind. 0–12.	Amount of Cloud. 0–10.	Max. in Shade.	Min. in Shade.	Max. in Sun, Black Bulb *in vacuo*.
1889.	Ins.	°	°			Ins.	°	°			°	°	°
August ..	30·51	72	62	2	3	30·48	76	72	3	4	83	58	128
September	30·41	74	70·9	2	3	30·38	79·4	72	3·4	3·8	83	57	132
October ..	30·39	77·8	73·9	2	4	30·36	80·7	74·4	3	3	83·8	61·2	136
November	30·29	83·4	78·6	2·6	3·4	30·25	85·3	80·2	3·7	3	87·3	64·6	143·5
December	30·23	84·7	79·7	2·7	4·6	30·17	86·3	80·8	3·7	5·9	89·2	67·3	144·5
1890.													
January	30·25	83	78	2·4	4	30·21	84·8	79	3·9	4·5	88·4	70·6	148·9
February	30·23	82·8	78	2	7	30·19	84	79	3	4	87	71	144
March ..	30·34	82	78	2	3	30·21	84	80	3	4	87·4	73	144
April	30·31	83	78	2	4	30·29	84	79	3	4	86	67	139
May	30·36	77·7	72·3	3	4	30·34	79	73	4	4	84	60	131
June	30·44	72·3	63	2·8	3·8	30·41	78·4	71·9	3	4·7	80·6	57	127
July	30·45	74·3	69·6	3	4	30·43	77·8	72·7	3	4	80·4	57·7	130

HALOS AND PARHELIA AT CAROWA, NEW SOUTH WALES, October 10th, 1890. By H. C. RUSSELL, B.A., F.R.S., Government Astronomer.

ON the afternoon of October 10th, 1890, Mr. James Crawfurd Leslie, Editor of the *Carowa Free Press*, and his three sons observed parhelia about the sun. The weather threatened rain, and a change was coming on. An immense halo appeared round the sun, a portion of it being below the horizon, as shown in the sketch; on either side of this at the same altitude as the sun was a mock sun. Soon after this a brilliant and well-defined but inverted rainbow became apparent in the zenith, and closer observation revealed a ring of light joining the halo and the rainbow. Where this ring of light crossed the halo was a third mock sun. The sun's rays appeared to project through the two horizontal mock suns. The whole display lasted about 30 minutes, and was witnessed by a number of persons in addition to those named.

At my request Mr. Leslie made full inquiry to ascertain if any one had seen rings of light cutting the halo at the points where the mock suns were, but no one saw them. Mr. Leslie's sons had observed carefully, and two prepared drawings from which the engraving was made. The halo and parhelia were also observed at Albury, about 30 miles east of Carowa. Carowa is on the north side of the Murray River, about 30 miles west of Albury.

ZENITH



HORIZON

THE SEA-BREEZE.

THE New England Meteorological Society in 1887 undertook an investigation of the Sea-Breeze, and have now published a Report[1] on the same which has been prepared by Prof. W. M. Davis, Sergeant L. G. Schultz, and Mr. R. De C. Ward. The Report concludes as follows :—

"The sea-breeze must be reckoned as one of the minor climatic features of New England. In the summer of 1887 it took possession of a narrow strip of the Eastern Coast of Massachusetts on 30 days, and judging by the weather of that season, this number may fall somewhat below the normal for the same period in other years. The occurrence of the breeze depends on the general weather of the region; it appears most distinctly on warm, clear, quiet days, and is absent on cool, cloudy, and rainy days, and on days with strong winds of any direction. It comes in to the shore from the sea, working its way against a belt of calm air, as is the case with the tropical sea breeze; and it exhibits the veering with the sun as the day passes that is noticed in winds of its kind elsewhere. It reaches the shore commonly between eight and eleven o'clock in the forenoon with a velocity of 10 or 15 miles an hour, its velocity rapidly diminishes inland. Its inland advance from the shore-line is made at first at a rate of from three to eight miles an hour, but slower afterwards when approaching its greatest penetration of 10 or 20 miles in the late afternoon. It produces a distinct and agreeable depression of temperature on the coast, but this effect is not carried inland as far as its wind extends; neither is the effect as great as that produced by the "sea-turn," or Easterly cyclonic wind of our coast. The district of most persistent occurrence and greatest penetration of our sea-breeze is from Boston to Cape Ann, along what is known as the "North Shore," where the north-east trend of the coast-line favours its development in combination with the prevalent South-westerly wind of summer time; South of Boston and North of Cape Ann, the South-westerly wind often reverses it or drives it away in the afternoon.

"The origin of the breeze is to be looked for in the diurnal excess of the temperature of the air over the land above that over the sea, in the manner best stated by Captain Seemann. The breeze is part of a littoral convectional circulation, but in the morning, while the temperature over the land is rising rapidly and the convectional circulation is in process of establishment, the outward expansion of the land-air holds the in-coming breeze off-shore for a time, thus causing its first appearance to be not close on the coast-line, but in the offing like 'a fine, small, black curve upon the water, when all the sea between it and the shore not yet reached by it is smooth and even as glass in comparison,' as Dampier long ago observed."

RECENT PUBLICATIONS.

ABHANDLUNGEN DES KÖNIGLICH PREUSSISCHEN METEOROLOGISCHEN INSTITUTES. Herausgegeben durch W. VON BEZOLD, Direktor. Band I., Nos. 1-3. 1890. 4to.

This contains three papers, viz. :—1. Die Veränderlichkeit der Lufttemperatur in Norddeutschland: von Dr. V. Kremser (32 pp.). This deals with variable periods of years, so that the results for different stations are not rigidly comparable with each other.—2. Bericht über vergleichende Beobachtungen an verschiedenen Thermometer-Aufstellungen zu Gr. Lichterfelde bei Berlin: von Dr. A. Sprung (27 pp.). This gives an account of the comparison of a great number of different thermometer exposures, which were read six times a day. The principal results are that all the window exposures were in excess, but in screens like Wild's or with thermometers quite open, if perfectly sheltered from the sun, they give very accordant results. Of the free standing screens Stevenson's, at least that of the Royal Meteorological Society, comes out decidedly the

[1] *Annals of the Astronomical Observatory at Harvard College.* Vol. XXI. Part II. 1890.

best. Dr. Sprung, however, points out that the perfectly open exposure of a thermometer screen is even harder to obtain than that of a rain-gauge, and he also points out that if the thermometers are far from a house readings may be carelessly taken. As a final conclusion the Prussian Institute recommends that window screens should be used in general, and that if no suitable window is available the Stevenson screen should be employed.—3. Bericht über vergleichende Beobachtungen an Regenmessern verschiedener Konstruktion: von Dr. G. Hellmann (13 pp.). The rain gauges tested were all German, as one most important particular to be ascertained was the fitness of the gauges for catching snow. As regards the measurement two collecting funnels and cylinders are supplied with each gauge, and if snow has fallen the empty cylinder is to be placed on the gauge and the full one taken into the house to thaw. The gauge recommended is Hellmann's, a 6-inch cylinder, with brass conical rim sharply cut at top. The rims are all stamped on testing, and any showing an error of ±0·3 mm. are rejected.

AMERICAN METEOROLOGICAL JOURNAL. A Monthly Review of Meteorology and Medical Climatology. January-March 1891. Vol. VII. Nos. 9-11. 8vo.

The principal original articles are:—The New England Meteorological Society (10 pp.). This is an account of the proceedings at the Meeting of this Society on October 21st, 1890, when the special topic of Tornadoes was discussed.—The Meteorological Observatory recently established on Mont Blanc: by A. L. Rotch (4 pp.). A cabin has been built on Mont Blanc at an altitude of about 14,320 ft. above sea-level, at which a set of recording instruments, by MM. Richard Frères, has been installed, thus rendering this the highest meteorological station in the world.—The Gervais Lake Tornado: Is a modern fire-proof building tornado-proof? by P. F. Lyons (6 pp.).—Photograph of the Lake Gervais Tornado Funnel: by the Editors (7 pp.). A reproduction of this photograph is given, the Editors having assured themselves both of its authenticity and also that the plate had not been "touched-up."—Observations and Studies on Mount Washington: by Prof. H. A. Hazen (12 pp.).—Accessory Phenomena of Cyclones: by H. Faye (7 pp.).—The State Weather Service: by Prof. F. E. Nipher (6 pp.). This was an address delivered by request of the State Board of Agriculture at Jefferson City, Ma., January 15th, 1891.—Wind Pressures and the measurement of Wind Velocities: by Prof. C. F. Marvin (10 pp.).—Meteorological Observations taken in four Balloon Voyages: by W. H. Hammon (31 pp.). These ascents were made under the direction of the Signal Office in January, March, and April 1885. The observations are given *in extenso*.—Prof. Russell's Theory of Cold Waves: by S. M. Ballou (14 pp.).—Temperature in High and Low Areas (8 pp.).—State Tornado Charts: by Lieut. J. P. Finley (6 pp.). The State here dealt with is New York.

DAS KÖNIGLISH PREUSSISCHE METEOROLOGISCHE INSTITUT IN BERLIN UND DESSEN OBSERVATORIUM BEI POTSDAM. Aus amtlichem Anlass herausgegeben VON W. VON BEZOLD, Director. 1890. 4to. 76 pp. and 4 plates.

This is an account of the organisation of the Prussian Meteorological Office; it is uniform in size with a similar account of the Astronomophysical Institution. The pamphlet gives a history of the gradual development of meteorological organisations in Germany, from the date of the Societas Meteorologica Palatina in 1780.

JOURNAL OF THE SCOTTISH METEOROLOGICAL SOCIETY. Vol. IX. Third Series. No. VII. 8vo. 1891.

This part contains a number of papers discussing various observations made at the Ben Nevis Observatory, among which are the following: (1.) Meteorology of Ben Nevis; by Dr. Buchan (11 pp.).—(2.) Daily mean temperatures at Ben Nevis Observatory and Fort William: by R. T. Omond (5 pp.).—(3.) Reduction of estimated wind forces to velocity in miles per hour at Ben Nevis Observatory; by R. T. Omond (1 p.).—and (4.) Thunderstorms at Ben Nevis Observatory: by R. C. Mossman (6 pp.). The other papers are: Influenza and Weather of London: by Sir A. Mitchell and Dr. Buchan (12 pp.); and Hygrometry in the *Meteorological Journal:* by C. Piazzi Smyth (2 pp.).

Meteorologische Zeitschrift. Herausgegeben von Dr. J. Hann und Dr. W. Köppen. December 1890-March 1891. 4to.

The principal articles are:—Untersuchungen über die Ursachen der unperiodischen Luftdruckschwankungen: von F. Klitzkowski (14 pp.). This is an attempt to give a mathematical explanation of the causes of storms on the basis of Dr. Werner von Siemens' papers, which have been noticed in this *Journal* for January (p. 44).—Bühler's Hagelstatistik und vorläufige Mittheilung einer säkularen Periode der Hagel- und Blitz-Gefahr: von C. Lang (9 pp.). The report reviewed refers to the hail records of Würtemberg for 60 years, 1828-87. It deals solely with damage done by hail as recorded in the Government Insurance Offices, and so does not go *pari passu* with thunderstorm inquiries; and it also treats only of the months at which crops are growing, &c. Speaking generally, Bühler recognises that maxima of hail damage coincide with minima of sun spot frequency; but although he has a period of 60 years, his figures do not give a very regular curve. It appears, moreover, that the frequency of hail is not increasing, but the contrary. As regards the alleged protection given by woods against damage, Dr. Bühler is unable to find any confirmation of the belief, and says that the question is inextricably mixed up with that of the influence of hill and valley.—Ein Apparat zur Ventilation des feuchten Thermometers: von Dr. R. Assmann (9 pp.). This is a description of the mode of ventilating the wet bulb by means of an aspirator, and Dr. Assmann contends that his plan insures a definite reading of the wet bulb, even in frost, in five minutes; whereas, when the bulb is left to itself, it often takes half-an-hour before the reading becomes steady.—Ueber den Einfluss des Waldes auf die periodischen Veränderungen der Lufttemperatur: von Dr. A. Müttrich (21 pp.). The author discusses the same subject as was treated of lately by Herr Eckert for Austria, but deals with fuller material. He has 15 years' observations nearly complete for 16 stations in North Germany. The results are worked out in great detail, but the minutiæ are hardly of general interest.—Ueber die ältesten meteorologischen Beobachtungen von Wien: von J. Leznar (10 pp.). This is a discussion of the observations of Pilgram in Vienna from 1762 to 1786. Dove quoted his figures as daily temperatures; but for most of the time they were early morning observations, probably taken at 6 a.m., and consequently too low. His thermometers were self-made, and probably not quite correctly marked at the fixed points. Pilgram must have been a bit of a wag. The Mannheim Academy proposed a scale of 1-4 for the wind. He said: "For the country and small towns the scale is good enough, but how shall we notice the motion of foliage in a city? We must only understand that we are to observe the foliage of the gardens the ladies wear on their hats, and the scale would be:

1. A wind which moves the wreaths.
2. Blows away the wreaths.
3. Blows away the hats.
4. Blows away the ladies, hats, and all."

—Zur Beurtheilung der Evaporationskraft eines Klimas: von Dr. M. Ule (5 pp.). This is an attempt to set at rest the question whether we should give relative humidity, or difference between that and saturation, or any other of the various modes of attacking evaporation. Dr. Ule suggests the following formula:—

$$\text{Evaporation} = A\Sigma\,(t\text{-}t')\,w.$$

Σ Implies that $(t\text{-}t')$ is to be calculated for each observation during the time for which the evaporation is to be determined and w is the wind. Dr. Ule admits that his formula would show no evaporation if a calm occurred, but otherwise his figures are fairly consistent *inter se.*

Sailor's Hand Book of Storm Track and Ice Charts. By Lieut. John P. Finley, Signal Corps U.S. Army, &c.

Lieutenant Finley says in his Preface that "the subject under discussion in this volume relates directly to the distribution and frequency of atmospheric disturbances, and the attendant movements of fog and ice over certain portions of the North Atlantic Ocean."

The construction of the charts is next explained. Then come explanatory tables, and finally the charts themselves, which we shall take in the order in which they appear.

1. Storm Track Charts. Of these there are 12, one for each month, representing the tracks of storm centres for the period of 10 years, 1875-84. These tracks are represented by a mass of confused lines covering the northern portion of the Ocean, and so interlaced one with another that individual tracks can scarcely be followed. Lieut. Finley states:—"By a storm centre is meant the centre of a region in which gales of the force of 4 to 6 on Beaufort Scale are experienced." There must be some misconception here, as the lowest figure for a gale on Beaufort's Scale is 7. Perhaps Mr. Finley refers to the Land Scale (0—6), but that is not Beaufort's.

2. Hurricane Chart. This possesses the same defect as the preceding series. The lines interlace and are almost undecipherable. The chart also is very badly lithographed, which renders it less legible.

3. Hurricane Chart of the Gulf of Mexico. This is much clearer. It would be improved if drawn on a larger scale.

4. Storm Frequency Charts. Of these there are 12 monthly and one annual chart, 13 in all. They are much clearer than the Storm Track Charts, and are interesting.

5. Fog Charts. These are monthly, and they show by curves the "average," "probable," and "extreme" limits of their occurrence, mainly about the banks of Newfoundland. As to this classification, the "average" and "extreme" data are taken from the U. S. Hydrographic Office data, the "probable" data from Signal Service publications. The result of this combination of incongruous data is that in several months the "probable" area, so far from coinciding with the "average," is far beyond the "extreme" area, notably so from August to November! The fog region never reaches the British Isles!

6. Ice Charts. These resemble the fog charts, and are affected by the same confusion of ideas as to the "average," "probable," and "extreme" limits.

Symons's Monthly Meteorological Magazine. January-March 1891. Nos. 300-302. 8vo.

The principal contents are: The Frost of 1890-91 (6 pp.).—Hail Insurance (2 pp.).—Frost Penetration (2 pp.).—Grass Thermometers in time of Snow: by J. Baxendell (1 p.).—February 1891 (8 pp.). This gives details of the distribution of rainfall over the British Isles during the month, which was abnormally small. At many stations no rain whatever was recorded during the month.—Merle's MS. Observations A.D. 1337-1344 (1 p.).

Transactions of the Hertfordshire Natural History Society and Field Club. Vol. VI. Parts 1-3. 1890. 8vo.

Contains among other articles: A record of water-level in a deep chalk well at Odsey Grange, Royston, 1878-1888; by H. G. Fordham (6 pp. and 2 plates). The author gives the measurements of the water-level in this well on March 1st in each year, and also the annual rainfall. Comparing the results with measurements made in two other wells he finds that the movements of the water are slightly later in time in the deeper wells, on the higher ground at Therfield and Barley than at Odsey, while at the same time a close parallelism is maintained in the curves representing the changes of level in the three wells. The rise from November to March, and the subsequent fall, take place with more or less modification from the mean curve year by year; any abnormal development in the annual curve being generally associated with some exceptional condition relative to the autumn and winter rainfall, and but rarely to that of the spring or autumn. —Half a Century's Rainfall in Hertfordshire: by J. Hopkinson (10 pp. and map). There was 1 station at work during the decade 1840-49; 2 in 1850-59; 7 in 1860-69; 12 in 1870-79; and 18 in 1880-89; while in 1889 there were 30 gauges at work in the county. The mean rainfall during each decade was as follows:—

1840-49	1850-59	1860-69	1870-79	1880-89
25·82	25·50	26·11	27·97	26·74

The mean for the 50 years 1840-89 was 26·43 ins.

Transactions of the Royal Society of Edinburgh. Vol. XXXIV. 4to. 1890. 406 pp.

This is devoted entirely to an account of the Meteorology of Ben Nevis. It contains the detailed hourly observations made at the Ben Nevis Observatory, and the five daily observations at Fort William, from December 1st, 1883, to December 31st, 1887, and is prefaced by a Report by Dr. Buchan on the Meteorology of Ben Nevis, based on these observations. The Observatory Log Book is also given *in extenso*, which contains much valuable and interesting information, not only of a scientific nature, but also on the difficulties encountered by the assistants in carrying on the observations.

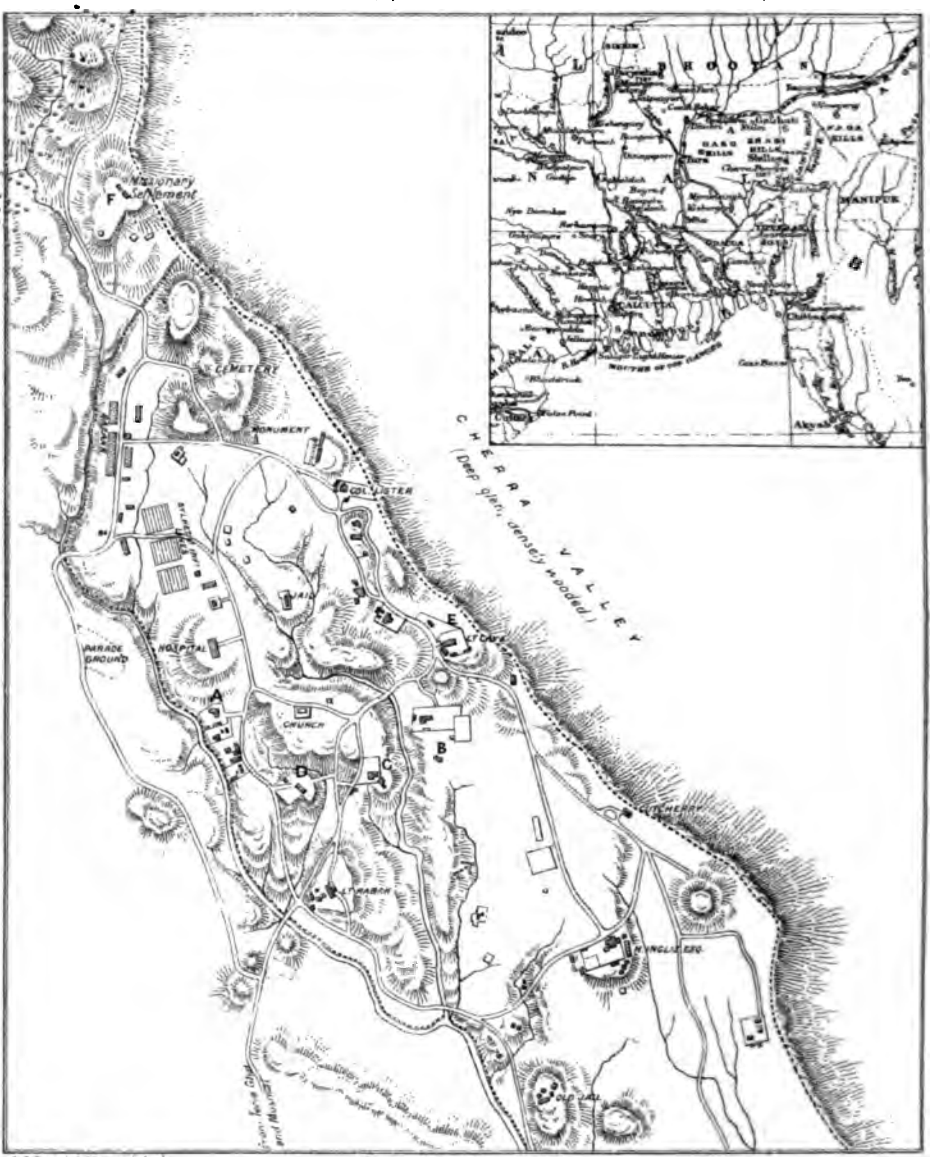
Weather Forecasting for the British Islands by means of a Barometer, the Direction and Force of the Wind, and Cirrus Clouds. By Capt. Henry Toynbee, F.R.A.S. 8vo. 1890. 86 pp.

In 1888 and 1889 Capt. Toynbee, at the request of the Council of the Meteorological Office, lectured on the use of the barometer to seafaring men at various ports in the North of Ireland and North-west of England. A desire was expressed that the lecture should be published: hence the present little manual. The object of the lecture is to show what a single observer can do towards forecasting wind and weather at his station, supposing him to have a barometer, means for observing roughly the direction and force of the wind, and power to recognise cirrus clouds and the direction from which they are coming. The work is illustrated with a number of plates and diagrams.

Zeitschrift für Instrumentenkunde. Neunter Jahrgang. March 1889. 4to.

Contains: Neue Registrirapparate für Regenfall und Wind, mit elektrischer Uebertragung: von Dr. A. Sprung und R. Fuess (8 pp.). This is a description of new electrical apparatus for recording rain and wind. As regards the former the authors use a lamp inside, as Babinet did in winter to melt snow. In the anemometer they use Robinson's cups, and a vane for direction. No account is given of the extent to which the battery is run out by the frequent changes of direction in a storm.

MAP OF THE STATION OF CHERRA POONJEE, KHASI HILLS, IN 1853.
SHEWING THE POSITION OF THE RAIN GAUGES.
ALSO KEY MAP SHEWING SITUATION AS REGARDS CALCUTTA AND THE BAY OF BENGAL.



A. S. Cattell & Co. Limd. Lith.

Scale 3 Inches – 1 Mile

// QUARTERLY JOURNAL

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A CONTRIBUTION TO THE HISTORY OF RAIN GAUGES.[1]

By G. J. SYMONS, F.R.S., Secretary.

[Read March 18th, 1891.]

OWING to the absence of our President in Oriental countries, it was felt by the Council that he could not be asked to prepare the Address relative to the Annual Exhibition, and I was requested to do so.

This paper is therefore one of the series in which Hygrometers, Anemometers, Instruments for Travellers, Thermometers, Sunshine Recorders, Barometers, Marine Instruments, Apparatus for studying Atmospheric Electricity, Solar Radiation Instruments, and the application of Photography to Meteorology, have been successively dealt with. I regret that I cannot, in the time at my disposal, make this as nearly complete as some of its predecessors were. My difficulties have also been aggravated by the fact that I cannot ascertain that any one has ever attempted to deal with the subject—even Poggendorff, in his excellent *Geschichte der Physik*, devotes less than half-a-page to it, and has not carried the history back so far as I have been able to do.

We are indebted to Dr. Hellmann for directing attention to what is probably the earliest measurement of rain, but, as will be seen, it was merely an

[1] By one of those curious coincidences which frequently occur, Dr. Hellmann was at work upon this subject at the same time as I was, and he has most kindly allowed me to use his data in the verification and completion of this Paper.—G. J. S.

isolated experiment, there is no suggestion of a rain gauge, or of a continuous record.

In an extremely interesting article[1] in a German periodical, Dr. Hellmann calls attention to a letter dated June 10, 1639, and addressed by B. Castelli to Galileo, in which he relates that after going to see a lake which was exceptionally low, he, on his return to Perugia, passed for eight hours through an apparently exceptionally heavy rain. This suggested to him the problem how much such a rain might raise the lake, and so, on reaching home, he put out a glass cylinder about 5 inches in diameter and 9 inches deep, and at the end of an hour took it in, and measured the depth of water in it. He does not give it in figures, but in the letter draws a line about 0·4 inch long to represent the depth.

Further evidence that this was an isolated case, and that the idea of regularly recording the fall of rain did not occur to Castelli, seems to be afforded by the fact that all through the Cimento MSS., which range from 1654 to 1664, and in the record very carefully kept at the Monastery of the Angels at Florence from 1654 to 1670, there is no reference to a rain gauge, though frequent statements are made as to the fall of rain and of snow. Had such an instrument as a rain gauge been known, I feel sure that one would at once have been added to the instruments at the monastery.

Most curiously, the first rain gauge designed was not an ordinary one, but a recording one. In Birch's *History of the Royal Society* we read that on January 22, 166½, Dr. Wren (*i.e.* Sir Christopher Wren) showed his experiment of filling a vessel with water, which emptied itself when filled to a certain height. Later on, September 23, 1663, Dr. Wilkins was desired to write to Dr. Wren for his scheme of the instrument for recording all sorts of weather. On November 30, 1663, Dr. Wilkins acquainted the Society that he had received an answer from Dr. Christopher Wren concerning his promised weather-clock, together with the scheme thereof. The amanuensis was ordered to draw the scheme in great (*i.e.* to prepare a diagram) against the next meeting, at which it should be considered, together with the letter describing it. On December 9, 1663, Dr. Wren's description of his weather-clock, consisting of two wings that may be added to a pendulum clock, was read and ordered to be registered. I do not reproduce this drawing because for some reason Sir Christopher did not propose to record anything except wind—and we are dealing with rain gauges, not with anemometers. But the other Fellows wished it completed, and, after some debate, the matter was referred to the Council to consider of the expenses, and of the most convenient way of reducing the engine into practice, as also of additions to be made thereto, whereof some were mentioned by Mr. Hooke, one of the officers of the Society. The Council was evidently alarmed at these additions, for five days later (December 14, 1663) it was ordered that Dr. Wren be desired to make an estimate of the charges of a plain weather-clock, such as he himself had devised; and to consider of the easiest contrivance to put it in practice.

[1] *Die Anfänge der Meteorologischen Beobachtungen und Instrumente.* Himmel und Erde II. Jahrg. 3 u. 4 Heft.

In 1664 (August) Hooke was provided with a residence in Gresham College (then the headquarters of the Royal Society), and directly afterwards, September 14, 1664, it was ordered that Mr. Hooke contrive a pendulum clock applicable to the observing changes of the weather, as well and as cheap as he could, for the use of the Society. In the following January Hooke showed the way whereby a thermometer might be made to indicate in connection with the weather-clock.

Then for several years nothing was done, but finally, on May 19, 1670, it was ordered that a weather-clock should be bespoken by Mr. Hooke; such a one as Dr. Wren had formerly contrived, for observing [recording] not only the winds and their quarters and degrees of strength, but also the quantities of rain, and other particulars relating to the temperature of the air.

It was thus nearly ten years between the date of Sir Christopher's suggesting his tipping-bucket rain gauge, and one being ordered for construction for the Royal Society. My impression is, however, that Sir Christopher, after showing his rain gauge to the Royal Society on January 22nd, 1662, took it home again, and recorded it regularly, although no trace of his observations can now be found. My reasons for this opinion are two: first that such a course was probable; secondly, that to a review of Perrault's *Origine des Fontaines* in the *Phil. Trans.* Nov. 22, 1675, there is the following note:—

"The like to which hath been attempted here, and proposed to the R. Soc. some years since, by Sir C. Wren, who by the contrivance of a rain bucket had taken an account of all the water that fell for a considerable time, and by his weather-clock had, among other particulars, not only taken in the measurement of the quantity of rain that falls, but also when it falls, and how much at each time."

It had long been supposed that the observations made by Mr. Townley, of Townley, near Burnley, Lancashire, which began on January 1st, 1677, were the earliest in the world, but Poggendorff has shown that an unknown correspondent residing at Dijon had supplied Mariotte with records from that city dating back to about 1674, or three years before the Townley ones.

On carefully reading Mariotte's works, I found a reference to a rather scarce anonymous book, entitled *De l'origine des Fontaines*, printed in Paris in 1674. It is, of course, in old French, but of such interest that I think a few lines from p. 200 should be reprinted *verbatim*.

> "Par les obfervations que j'ay faites de la quantité des eaux de pluye & de neige, j'ay trouvé que depuis le mois d'Octobre 1668, jufques à pareil mois de 1669, il en eft tombé la hauteur de dix-huit poulces fept lignes: Depuis pareil mois de l'année 1670, jufques à pareil mois de 1671, il n'en eft tombé que la hauteur d'onze poulces fix lignes feulement; & depuis le mois de Ianvier 1673, jufques à pareil mois de 1674, la hauteur de vingt fept poulces fix lignes: Ie joins ces trois quantitez enfemble pour en faire celle d'vne année commune, qui fera par ce moyen de dix-neuf poulces deux lignes vn tiers."

I had, from internal evidence, arrived at the conclusion that these observations were made in Paris, but thanks to the help of Mr. White, the Assistant Librarian of the Royal Society, the veil of anonymity is removed, and the observations prove to have been made in Paris by M. Pierre Perrault, in whose collected works the above anonymous book is reprinted with his signature.

Perhaps a brief digression respecting what led Perrault and Mariotte to make, and to have made, these observations, may be excused. Science made rapid advances during the years following the discovery of the barometer in 1643: in 1648 there was Pascal's experiment on the variation of the barometer with altitude above sea-level, and in 1670 Mariotte proposed the synchronous study of winds over a large area, with a view to weather forecasting. Although the Biblical texts were perfectly clear as to the course of the vapour and the rivers (Job xxvi. 8; Isaiah lv. 10; Jer. x. 13; Eccl. i. 7); and Vitruvius, in his *Architectura*, had distinctly stated that springs were fed by stored-up rainfall, the matter had been so buried under false theories that the general opinion had swerved quite away from the truth, when Perrault took it up, and in the little book I have quoted, gave, first a thorough analysis of the many false explanations, and then the true explanation. For this he, of course, needed the returns of rainfall, and it is curious that his mean value for Paris 19″2¼‴ corresponds to 20·45 English inches, or within half-an-inch of the value for that city assigned by Prof. Raulin as the result of modern observation. M. Perrault dealt with the matter with great skill, considering the epoch. He had the rainfall, he allowed for evaporation, he made an estimate of the area of the watershed of the Seine and the Marne, and compared the probable discharge, with that of the combined rivers when passing through Paris.

Having started this question of priority I proceed to deal with, and dispose of it. I have placed Sir Christopher first on the list, because I believe that he was first, but I have attached a ? to the entry because I have not actual proof.

Doubtless the tables which I have prepared have faults. They are virtually challenges to the meteorologists of all countries, to prove, if they can, that they are entitled to higher positions than I have awarded to them; and although I have taken pains to do justice to all, I include the tables in the paper that they may be corrected if, and where, they need it.

The first table gives a list of all rain records commenced before 1700, viz.:

Country.	City or Place.	Observer.	Date.
? England,	London,	Sir Christopher Wren.	1662 ?
France,	Paris,	P. Perrault.	1668.
,,	Dijon,		1674 ?
England,	Townley, Lancashire,	R. Townley.	1677.
France,	Paris,	Sédileau.	1688.
,,	Lille,	Vauban.	1689.
England,	Gresham College, London,	R. Hooke.	1695.
,,	Upminster, Essex,	Rev. W. Derham.	1697.

In the next table I have had to deal not merely with meteorology, but with politics. The map of Europe, and of the World, is not the same now as it was 224 years ago, and this has caused some difficulty in forming a list of the countries of the world, in the order of date of first systematic record of rainfall—which is what I have tried to compile. I do not think that the first five entries will be easily wrested from France, England, Italy, Switzerland, and Ireland respectively, but that very probably the entries of the later dates, *e.g.* for the nineteenth century, will require both modifications and additions.

Quarters.	Countries.	Towns.	Dates.
Europe	France	Paris	1668
"	England	Townley	1677
"	Italy	Pisa	1707
"	Switzerland	Zürich	1708
"	Ireland	Londonderry	1711
"	Wurtemburg	Ulm	1712
"	Holland	Leyden	1717
"	Prussia	Breslau	1717
"	Scotland	Edinburgh	1731
"	Russia	St. Petersburg	1738
North America	South Carolina	Charleston	1738
Europe	Sweden	Upsala	1739
Africa	Madeira	Funchal	1747
West Indies	Antigua	———	1751
"	Martinique	St. Pierre	1751
"	St. Domingo	Haïti	1761
Europe	Austria	Kremsmünster	1763
"	Norway	Bergen	1765
"	Denmark	Copenhagen	1769
Asia	Madras	Madras	1777
Europe	Belgium	Brussels	1779
"	Spain	Barcelona	1780
West Indies	Guadaloupe	La Point à Pitre	1782
Europe	Portugal	Lisbon	1783
Asia	Bengal	Calcutta	1784
Africa	Mauritius	Port Louis	1786
South America	French Guiana	Cayenne	1788
West Indies	Cuba	Havanah	1811
Asia	China	Canton	1812
Europe	Bavaria	Baireuth	1814
Asia	Bombay	Bombay	1817
Europe	Baden	Freiburg	1817
Africa	Réunion	St. Denis	1818
"	Sierra Leone	Freetown	1819
South America	Brazil	S. L. de Maranhao	1821
West Indies	St. Vincent	Langley Park	1822

Quarters.	Countries.	Towns.	Dates.
North America	Mexico	Vera Cruz	1822
Asia	Burmah	Moulmein	1828
Europe	Iceland	Reikavik	1829
Africa	Guinea	Christiansborg	1829
South America	British Guiana	Georgetown	1831
Asia	Ceylon	Kandy	1833
Africa	Egypt	Cairo	1835
,,	Algeria	Algiers	1838
,,	Constantine	Constantine	1838
Australia	South Australia	Adelaide	1839
,,	Victoria	Melbourne	1840
,,	Tasmania	Hobart	1841
Asia	Java	Buitenzorg	1841
Africa	Oran	Oran	1841
West Indies	St. Thomas	———	1842
Oceania	Tahiti	Papéiti	1846
West Indies	Barbados	Husbands	1847
Africa	Senegal	St. Louis	1848
South America	Chili	Santiago	1849
West Indies	Jamaica	Up Park Camp	1853
Asia	Persia	Ooroomiah	1853
Africa	Madagascar	Nossi-Bé	1855
South America	Venezuela	Caracas	1860
Oceania	New Caledonia	Noumea	1860
Europe	Roumania	Bucharest	1862
South America	British Honduras	Belize	1862
West Indies	Sombrero	———	1863
Asia	Cochin China	Saïgon	1864
West Indies	Porto Rico	St. John's	1868
South America	Peru	Lima	1869

Early Rain Gauges.

I have not been able to find any details respecting the gauges used in Paris by Perrault in 1668, but that at Dijon in 1674 is stated by Mariotte to have been :—

"Un vaisseau quarré qui avoit environ deux pieds de diamètre, au fond duquel il y avait un tuyau qui portoit l'eau de la pluie qui y tomboit dans un vaisseau cylindrique."

As regards the first English observations, those made at Townley, near Burnley in Lancashire, in 1677, it would have been very interesting to give a drawing of the gauge, but as no engraving exists, we must be content with Mr. Townley's description, which is as follows :—"I fixed a round tunnel of 12 inches diameter to a leaden pipe which could admit of no water, but what came through the tunnel, by reason of a part soldered to the tunnel itself,

which went over the pipe, and served also to fix it to it, as well as to keep out any wet that in stormy weather might beat against the under part of the tunnel; which was so placed, that there was no building near it that would give occasion to suspect that it did not receive its due proportion of rain that fell through the pipe some nine yards perpendicularly, and then was bent into a window near my chamber, under which convenient vessels were placed to receive what fell into the tunnel; which I measured by a cylindrical glass, at a certain mark containing just a pound, or 12 ounces troy, and had marks for smaller parts also."

In this description there are a few points to be noticed: (1) that Mr. Townley was careful not merely that his tunnel was firmly fixed (I have known modern observers have theirs blown away), but also that no rain could trickle down the outside of the funnel and find its way down for measurement (as has subsequently occurred). On the other hand, Mr. Townley, like most early observers, was wrong in putting the tunnel on the roof of his house; many persons would imagine that in the 27 feet of pipe there would be evaporation and loss, but from actual measurements of a similarly mounted gauge I have found this error to be almost imperceptible.

The next earliest gauge of which I have details was that used at Gresham College, London, in 1695; this is shown in Fig. 1. There is a wooden frame to support the glasses (the funnel was apparently of glass), a large bottle called a bolt-head with a neck 20 inches long, and capable of holding above two gallons. The funnel was 11·4 inches in diameter, and steadied by two stays or pack threads strained by two pins to hold the tunnel steady against the high winds. The pipe of the tunnel being no wider than ¼ of an inch, the evaporation could be but little.

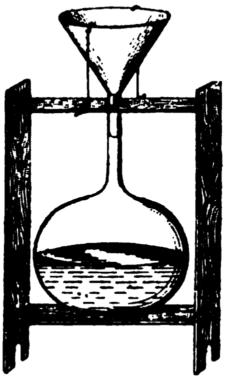

FIG. 1.

Rain Gauge used at Gresham College, London, in 1695.

The collected water was weighed every Monday morning in pounds, ounces and grains troy, and the amount was printed in that form, but the total was converted into, and printed as, the vertical depth which had fallen, viz. from August 12, 1695, to the same date in 1696, 181 lbs. 7 oz. 118 grains, or 29·11 inches.

I am not sure about the pattern of gauge used by the Rev. Mr. Derham, F.R.S., at Upminster, from 1697, but believe that it was very similar to Mr. Townley's, and similarly mounted.

As early as 1722 a close approach was made (by the Rev. Mr. Horsley, of Widdrington, Northumberland) to the modern principle. The following is the description :—

"The weighing the water and reducing it from weight to depth seemed pretty troublesome, even when done in the easiest method: to remedy this inconvenience (besides a funnel and proper receptacle for the rain) I use a cylindrical measure and gauge. The funnel is 80 inches in diameter, and the cylindrical measure exactly 8 inches, the depth of the measure is 10 inches, and the gauge of the same length with each inch divided into 10 equal parts; or, instead of a gauge, the inches and divisions may be marked on the side of the cylindrical measure. The apparatus is simple and plain, and it is easy to apprehend the design and reason of the contrivance; for the diameter of the cylindrical measure being just $\frac{1}{10}$ of that of the funnel, and the measure exactly 10 inches deep, 'tis plain that 10 measures of rain make an inch in depth, one measure 0·1 inch, one inch on the gauge 0·01 inch, and $\frac{1}{10}$ of an inch on the gauge 0·001 inch. By this means the depth of any particular quantity which falls, may be set down with ease and exactness, and the whole at the end of each month or year may be summed up without trouble."

I notice, however, that in 1742 the observer at Rome, Abbot Didacus de Revillas, speaks of his gauge, which closely resembled Mr. Horsley's as "Dr. Halley's method," so that possibly Mr. Horsley was not, after all, the originator of the pattern of rain gauge which he described.

Dr. Jurin was among the first, if not the first person, to draw up a code of rules for meteorological observers. It is not necessary to describe the rain gauge which he recommended, because it closely resembled the one just described, but it may be well to state that he is among the earliest to refer to the measurement of snow. He says: "Sextima et ultima altitudinem pluviæ, vel nivis in aquam resolutæ, quæ post superiorem observationem deciderit, per digitos *Londinensis* et earum partes decimales metiatur."

Considerable though not very satisfactory information respecting rain gauges is given in Leupold's '*Theatrum Staticum*,' folio, Leipzig, 1726. He devotes two and a half pages of text, and nine engravings to rain gauges, but his engravings are diagrams rather than drawings, and with the exception of Fig. 2 do not represent the rain gauges precisely as used.

He describes the rain gauge used from about 1717 at numerous stations by members of the Breslau Natural History Society as a sharp-edged glass funnel about 4 inches in diameter and 8 inches deep, divided to indicate the weight of water fallen into it, not the depth which it represented.

In Fig. 2 he represents a square gauge of his own design, about 9 inches square, and of which the contents were to be measured in a glass tube. Except that the upper rim should be sharp, that taps are always undesirable as they leak, and that his glass tube should have been divided to show depth, not weight, there is nothing to complain of in this, which, be it remembered was described and engraved more than 150 years since.

Leupold next describes another gauge, a square funnel leading into two glass tubes, a terrible apparatus invented by M. Leutmann, but I hope never used. He then gives a sketch which contains the germ of what is (wrongly) known as Stutter's recording rain gauge, viz. a trough with a series of compartments driven by clockwork under the orifice of a funnel, so that by measuring the fall in each compartment one would get the quantity during the respective intervals.

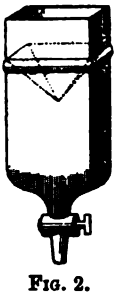

FIG. 2. Leupold's Rain Gauge.

Lastly, Leupold describes a second gauge of his own invention, which may be said to contain the germ of what is usually called Crosley's, and on the Continent (wrongly) Horner's. Leupold has under the point of his funnel a small bucket on one end of a balanced lever, when full it tips and empties, but in tipping turns a wheel one tooth, which carries a hand one division on a dial, and as there are four dials each 10 fold the other, the apparatus indicates up to 10,000 tips. There is an arrangement to prevent water passing out of the funnel while the emptying is in process. Leupold does not say that the instrument was ever tried.

In 1744 Mr. Pickering, F.R.S., proposed a gauge far inferior to that of Horsley (or Halley), and an engraving of it appears in the *Phil. Trans.* The funnel had an area of only one square inch; this led into a glass tube (of which in the engraving the diameter is exaggerated) ½ inch in diameter, and rather more than 2 feet long. In such a tube 1 inch of rain would stand about 5 inches deep, and Mr. Pickering says that he had each inch divided into 32 parts, the marks being lead pencil on white paint. He had this hung against the railings which went round the top of his house. I am not aware that any observations made with this gauge have been preserved.

I must not, however, dwell longer upon these antiquarian curiosities, but come down to modern times and try to point out the good and the bad features illustrated by the present Exhibition. I think that this will best be done by taking seriatim various features connected with rain gauges.

DIMENSIONS.

In the Exhibition we have a drawing of the largest rain gauge ever made (No. 121), and in (No. 15) almost the smallest—one being more than two thousand times as large as the other, and yet their indications do not differ by any thing like 5 per cent. Very large gauges by radiation become cool, and being cool condense some vapour which the soil or a small gauge would not; this makes them slightly exceed small ones. But in the experiments originated by Colonel Ward and subsequently continued with the same instruments by the Rev. C. H. Griffith and the Rev. F. W. Stow, it was proved that the difference between a gauge 1 inch in diameter[1] and one five hundred times its size was less than 2 per cent. Similar comparisons have been made elsewhere, both in this country and abroad, almost always, I believe, with the same result. This, however, does not prove that either very small or very large

[1] The smallest ever used.

gauges are desirable. With gauges less than 8 inches in diameter great care in measuring is necessary, because even one drop of water represents an appreciable depth of rain. With gauges exceeding 10 inches in diameter the volume of water to be measured becomes inconveniently large and heavy, *e.g.* in the large gauge at Rothamsted 1 inch of rain must weigh more than 2 cwt. That gauge excellently fulfils its object—the measurement of small falls, and the collection of water for analysis; but no one would suggest the general use of so formidable an apparatus.

Rims.

It was found out at a very early date that a rim round the funnel of a rain gauge was an improvement; and this is one of the points in which until a comparatively recent period there had been deterioration rather than progress. Among the gauges used in the eighteenth century (perhaps not so much in England as on the Continent) it was not at all unusual to surround the funnel with a vertical rim 6 inches high. In England, however, until the introduction of the Snowdon pattern gauge in 1864, the funnel nearly always reached *almost* to the top of the gauge. This was a pity, because if the funnel is not surrounded by a rim, if a fall of snow is accompanied by wind, hardly any of the snow will be left in the funnel; and I am afraid that most of the early English records are (for the winter months) too small, owing to insufficient attention to the measurement of snow.

I said just now *almost* to the top of the gauge, because, for nearly half a century, it has been the English practice, and is now nearly universal, that the actual top of the gauge shall be a turned brass rim. These rims deserve a word or two, because many observers buy rain gauges with bad rims. The objects of the rim are three: (1) by its solidity to keep the funnel in shape and prevent warping; (2) to define accurately the area within which rain drops are to be collected; (3) to cut any rain drop which falls upon it so that the true proportion of the drop shall go into the gauge for measurement, and the rest shall go away. As regards (1) solidity, any one can judge whether the rim is adequately firm. As regards (2) whoever verifies the gauge is responsible—and it will be a good day when the purchase of unverified gauges is abandoned. The third object is one which even opticians do not seem to understand. To cut a rain drop and send the two portions to their proper destinations a nearly vertical rim with an edge almost like that of a razor is necessary. There is a very fine specimen of what a rim should be on the gauge sent by Prof. Mascart (No. 38). See also Nos. 19 to 27. On the other hand, gauges Nos. 1, 2 and 4, which are old patterns kindly made specially for the Exhibition by Messrs. Negretti and Zambra, may be quoted as specimens of what rims should *not* be. A drop falling with driving rain on the sloping brass rim, and wholly outside of the true area of the gauge, will break into spray, and much of that spray will be blown into the gauge.

Weighing the Rain.

I have already mentioned that at Gresham College the rain was always weighed. At Townley, and at Upminster, and at many continental observatories, it was long the custom to report the rainfall by weight. I do not think that it was actually weighed, but that vessels were selected which held various fractions of a pound, and by pouring into them, the total weight was arrived at. Many of the older engravings indicate that each gauge had several measures of different sizes so as to be adapted to the amount to be measured. We have, however, seen that as early as 1722 Mr. Horsley had given up this roundabout process, and adopted a glass jar graduated in inches and decimals such as is in general use now. Weighing is now resorted to only when extreme accuracy is needed. A photograph of the Rotherham weighing machine forms exhibit No. 88.

Float Gauges.

I am not sure who first employed the rising of a float to indicate the fall of rain. I believe it is a British idea, and I do not remember having seen a float gauge on the Continent except in Breguet's Self-Recording Rain Gauge. A float was employed in a complicated gauge used at Gravesend by Mr. Kite in 1787, and three years later it seems to have been in general use, for in 1790 George Adams, Mathematical Instrument Maker to His Majesty, in "A short dissertation on the barometer, &c.," describes only one pattern of rain gauge, viz. a 12 inch contracted float; he points out the necessity for setting it to zero by putting in a little water, says that it was so arranged as to prevent evaporation, and that it was to be put in an open place where no house or other object could shelter it. In his list of prices it is marked 18s., his best Mountain Barometer being £9 9s. Further evidence in this direction is afforded by the fact that this pattern of gauge is the only one quoted in Cavallo's *Elements of Natural Philosophy*, 4 vols., 1803.

Float gauges may be divided into six classes, of which the features are: (1) uniform; (2) contracted; (3) rod attached; (4) rod detached; and as (3) or (4) may be adapted to either (1) or (2), we get the six possible varieties.

(1) Uniform, is represented in the exhibition by the small 8-inch Fleming gauge (No. 14), and it has feature (3), viz. the rod attached. This is very bad, especially with so small a gauge, because rain rarely falls vertically, and as the rain falls the float rises, and carries up the rod. Now, suppose that only 2½ inches of rain have fallen (and this gauge is supposed to hold ten or more inches), the rod will have risen 2½ inches above the rim, and if the rain is falling at an angle of 45° the rod will be intercepting rain, which, but for the rod, could not, and should not, be led into the gauge. Few persons would credit how serious this error is—I must, therefore, give some facts, on the authority of the *Report on the Supply of Surplus Water to Manchester, &c.* by S. C. Homersham, C.E., 1848.

In 1844 the Manchester Literary and Philosophical Society put on the hills east of the city some rain gauges which possessed the features (1) and

(8). It shortly afterwards occurred to Mr. J. Wood, who was resident engineer to the Peak Forest Canal, and near to whose residence one of these gauges was erected, that the rod must intercept much rain which ought to go over the gauge—so he had a gauge made with a cover to it, and a rod of the same size as that in the Society's gauge, *i.e.* ½ inch diameter and 12 inches long, standing up through a hole 1 inch diameter in the centre of the said cover. The water intercepted by the stick and running down it and passing through the hole in the cover amounted to

		Ins.
1845	...	21·95
1846	...	15·40
1847	...	22·48
Mean	...	19·94

Nearly 20 inches a year. I have been told, but cannot vouch for the fact, that these faulty gauges led the Corporation of Manchester to grant compensation water far in excess of the proper amount, and which they had to buy off for £120,000.

(2) Contracted float gauges—of which Messrs. Negretti have kindly made a specimen (No. 2)—are unsafe in any country liable to frost, because the contained water, on freezing, bursts the cylinder—and as they were always made with (8) the rods attached, and their rods (owing to the contraction) rise two, three, four, or even five inches for each inch of rainfall, the error arising from these rods intercepting the rain was very serious. It is sometimes stated that these rods can be pegged or tied down—but that merely substitutes a lesser evil for the greater; if the rods are fastened down, the floats are immersed; and if the floats are immersed, the water surface is uncovered and liable to evaporation.

(4) Detached rods. Float gauges with detached rods are, in my opinion, very useful for monthly gauges, and for engineering work. If the rod is absent, it cannot be tampered with, and no one without the proper rod can read the gauge. The float nearly covers the water, and so checks evaporation. The gauge being long is sunk deep into the ground where the water is not liable to be frozen, and the gauge will hold a large quantity. If it be desired to have records true to $\frac{1}{20}$th of an inch, all that is requisite is to contract the inner cylinder as in No. 24.

Side Tube Gauges.

We have in No. 1 a fine specimen of a pattern of rain gauge, introduced by Mr. Simms (of the firm of Troughton and Simms) in 1835, but now happily rejected. It was handy, and handsome, and if one could find a locality of which the temperature never fell below 40° or rose above 60°, a gauge of that sort would give tolerable results. It would show too little, because it is arranged to stand about 5 feet above the ground, where it would collect about 8 per cent. less than if its funnel were at the regular height of 1 ft. That, however, is its least fault. In hot weather the water in it becomes

scaldingly hot and evaporates accordingly, and in winter the water freezes and bursts both the copper body and the glass tube. Add to that the fact that taps soon corrode and begin to drip, and it will be sufficiently evident why I say that it is a pattern to be avoided.

I ought here to refer to the continental, or perhaps I should have said, French variety of this gauge. In its early form there was no contraction, the water therefore simply rose in the tube according to the rainfall, an inch for an inch. I never saw a gauge of this pattern, but it was engraved in Pouillet's *Elemens de Physique* in 1832, and has been copied into similar works *ad nauseam*. This copying, however, has one advantage, it indicates plainly what a large proportion of most treatises on Physics consists of repetition; but that is a digression. The modern French modification of this gauge is shown in No. 89, which must be very trying to those who use it during driving snow storms. The lamp, to prevent the water in the body from freezing, must be kept alight in spite of the wind; it must give heat enough to warm the body and melt the snow, and yet not enough to send off the melted snow as vapour. Moreover it holds very little, and if it overflows the record is lost. No. 88 is a far more trustworthy gauge.

Howard's Gauges and Modifications thereof.

Howard's 5-inch funnel, bottle, and measure, are so well known that it seems almost heresy to suggest that it was not wholly original, but really there is not much room for absolute originality in a rain gauge. Dr. John Dalton, F.R.S., in his *Meteorological Observations*, 1788, does not give full details as to his rain gauge, but I think that it was a 10-inch diameter circular funnel leading into a glass bottle, and the measurement by a jar, just such as we use now. Dr. Garnett also (*Trans. R. I. Acad.* V. (1724) p. 257) used a funnel, bottle, and jar, and he represents his funnel as provided with an "umbrella," *i.e.* a shield to prevent rain on the *outside* of the funnel running down into the bottle and being measured. To Howard, however, I think that we are indebted for two features, of which one was entirely new, viz. the turning of the brass rim so as to ensure great accuracy as to size and shape, and also for directing attention to the importance of the horizontality of the funnel. As regards the modifications, they are set out clearly in the Catalogue Nos. 6 to 10, and 21 and 22, and therefore need not be dealt with here.

Taps.

I do not know that taps are made better on the Continent than they are in England, or that continental climate has less effect upon out-of-door taps than is the case in England, but if neither of these conditions are true, it is difficult to understand the frequent use of taps in foreign rain gauges. In this country, after four or five years' exposure to the weather, a tap nearly always begins to drip. Are continental taps better? or do our continental friends regard the drip as trivial? I am very glad to see that Dr. Hellmann's latest pattern No. 48 has no tap, and Prof. Mascart's No. 88 has none. That almost looks as if the days of taps for rain gauges were drawing to an end.

Mechanical Gauges.

As already mentioned, the first rain gauge in which the collected rain water was utilised to register its amount was designed by Sir Christopher Wren; it was a wedge-shaped bucket which, when filled to a certain height, tipped and emptied itself.

In 1725 we have a very similar arrangement shown in Leutmann's *Instrumenta Meteorognosia inservientia*.

About 100 years later, in 1827, Mr. J. Taylor[1] had a gauge made in which the water was led over a sort of water wheel with heliacal buckets; the increase of the weight of water in one bucket caused the wheel to turn until its weight became such that it passed from under the conducting tube and another took its place, each change causing a hand to advance one division over a clock-like dial.

In (or before) 1829 a gas meter maker named Crosley brought out a gauge with a modification of Sir Christopher Wren's bucket, and attached to it a train of wheels similar to those he used for gas meters, and thus we have the so-called Crosley rain gauge, of which we have three forms in the Exhibition, Nos. 30, 31 and 32. If every observer would do as one of the earliest purchasers of one (now long deceased) told me he did, Crosley gauges would not have so bad a character as they now have. My friend, the Rev. W. Steggall, of Thurston, Bury St. Edmunds, bought his Crosley gauge in 1833, and he arranged that on New Year's Eve every year a watchmaker from Bury St. Edmunds should go out to Thurston Vicarage, thoroughly clean and oil the gauge, and start it at zero for the new year, finishing up with a substantial supper and a drive back to Bury St. Edmunds. Modifications of Sir Christopher's tipping bucket enter into many patterns of self-recording rain gauges.

In (or about) 1830 this was followed by J. K. Horner's vibrating double bucket gauge, which is fully described and illustrated in Kämtz's *Lehrbuch der Meteorologie*, Vol. I. p. 412 it is nearly identical with Crosley's.

Self-Recording Rain Gauges.

I mention these only that it may not be assumed that I have forgotten them. It is, however, quite impossible to say in this paper anything useful upon a subject to which I have already devoted more than 30 pages of different volumes of *British Rainfall*, and to which nearly another 30 pages would require to be added.

Storm Rain Gauges.

These are I think dealt with sufficiently in the Catalogue. *See* Nos. 28 and 29.

Peculiar Rain Gauges.

One of the queerest rain gauges of which I have read was the De Witt gauge, of which a large number was distributed in the United States between

[1] *Phil. Mag.* Vol. II. p. 406.

1827 and 1840. As regards the State of New York, this led to the spoiling of all the rainfall work at the Academies, for when these gauges were issued the observers were told to continue their old gauges for comparison with the new ones. As far as appears from the published volume, not one of them either did that, or reported the date at which the De Witt gauge was taken into use. The De Witt gauge (first pattern) was simply a tin cone, 9 inches deep and 5 inches in diameter—it had no receiver—the water remained in the funnel (except what dried up); the funnel had no rim; we are not told how it was to be stuck up and kept level; a cone of this size would when brimful hold only 3 inches, and even with two inches a very large proportion would splash out: and the measurement was very funny, a stick was to be graduated (of course unequally) in accordance with an elaborate table, and this stick was to be plunged into the funnel with no arrangement to secure verticality, and with no correction for the displacement which the stick would produce. The second form of De Witt's gauge was even more comical. I do not know how its contents were to be measured, but it consisted of two funnels, one base upwards, as in his first pattern, the other a smaller cone, base downwards, and resting in the other cone. Anyone would be doing a service to students of American rainfall who made a list of all places to which De Witt's gauges were supplied, and of the years during which they were used.

A spherical gauge is, in my opinion, another eccentricity, for the use of which no good reason can be given, and yet so able a man as the late Dr. Robinson used one at Armagh Observatory for many years from about 1836, and Mr. J. Atkinson (whose rain map No. 102 is one of the rarest items in the Exhibition) tried one near Carlisle in 1840. I do not understand what advantage is aimed at: a ball nearly as large as the funnel was placed in it, like an egg in an egg-cup, but the outsplashing must be enormous, hail could never get in, and with snow, the whole thing would become ridiculous.

Staff gauges were another eccentricity, arising probably from Mr. Wood's experimental demonstration of the errors of float gauges with attached rods. I do not know whether he or Mr. Homersham was responsible for introducing them; the latter, however, in his *Report, &c.*, 1848, sets out the theory of the gauge, and shows that he did not understand it, because he calculates upon intercepting a strip of rain equal to half the *circumference* of his rod, whereas he would really obtain one equal to its *diameter*, which gives him an error of rather more than 50 per cent. to begin with—but in so wild a scheme that is perhaps a small portion of the total error. Possibly, I ought to give an idea of what the scheme was. A rod was to project vertically into the air, which rod passed, without touching, through a hole the sides of which were everywhere ¼ inch distant from it. The length and surface of the stick *plus* the area of the hole through which it passed were made equal to the area of a 9-inch horizontal mouthed gauge, viz. 63·61 inches. The calculations were:

Diameter of rod 2 inches ; semi-circumference 3·142
Length of rod 18·75 inches
Surface of rod = 3·142 × 18·75 = 58·7
Area of aperture ... ... 4·9

Total area ... ... 63·6

But evidently for the semi-circumference he should have taken the diameter, and then his area would have come out 42·4 instead of 63·6 The whole idea is, however, based on the fallacy that the rain falls ?! horizontally. Assume a vertical rain, the area exposed is less than 5 inches, and the water falling on it is to be measured by a glass adapted to a gauge more than twelve times as large. Moreover what record would a staff gauge give of a hailstorm!

METEOROLOGICAL PHOTOGRAPHY.

Abstract of an Address delivered to the Royal Meteorological Society, on March 18th, 1891.

BY ARTHUR W. CLAYDEN, M.A., F.G.S.

MR. CHAIRMAN AND GENTLEMEN,

BEFORE I show the photographs which I have brought here to-night, I wish to say a few words in explanation of the object with which they are produced.

Last year, at the Leeds Meeting of the British Association, Mr. John Hopkinson, who is familiar to most of us as a Fellow of this Society, proposed the election of a small Committee to take up the subject of Meteorological Photography. The work which had already been done by the Committee on Geological Photography had been so satisfactory, that it was felt desirable that other sciences should be given a similar chance, and thanks to Mr. Hopkinson's initiative and the cordial support he received from Mr. Symons, the task was entrusted to four of us, viz. Mr. Symons, who is our Chairman, Professor Raphael Meldola, Mr. Hopkinson and myself, the duties of Secretary falling to my share.

Now, Sir, it must occur to every one that the collection of Meteorological Photographs and the study of the applications of Photography to the purposes of our Science, is a work which this Society has carried on for some considerable time; and indeed a glance round the walls to-night will show how keenly the importance of this work is appreciated. Some of those who are here to-night may, therefore, be disposed to think that we who compose the British Association Committee, are setting up, so to say, a rival establishment. Upon this point I had hoped that Mr. Symons might have said a word or two; but as he has left it to me, I can assure you that there is no

thought of any such thing. When I was first asked if I would serve on the Committee, I felt that whatever results it might attain could not fail to be of advantage to Meteorology, and so of value to our Society. This view I am happy to find has been fully taken by the other Members of your Council, who have already lent us most valuable assistance. Indeed we are indebted to them for this opportunity of appealing to the Fellows for their invaluable co-operation.

Before discussing the scientific aspects of our work, perhaps I may be allowed to point out another advantage which I feel certain should follow from a development of Meteorological Photography. There are two ways of advancing a science. The first is, of course, by the discovery of new facts and new laws. Upon this I shall touch later this evening. At present I wish to emphasise the importance of the second method, which is to attract more students and diffuse that knowledge which exists. Now Meteorology is generally regarded, by what I may call outsiders, as a very "dry" subject. We ourselves know well enough the interest and value of long columns of instrumental observations. But to the uninitiated they are meaningless, or at best wearisome in the extreme. Every one, however, can appreciate the beauty or interest of a photograph, and I believe that we have an opportunity before us of enlisting very many recruits. We shall show, as the Society has already shown, that there are sections of our Science which, for general interest, will stand second to none. The observations of clouds and lightning are both subjects which every one can appreciate; and I hope that Photography may be the means of starting many people on the study of Meteorology by presenting to them the more picturesque and popular aspects of the Science. Once arouse interest, and weather charts, instrumental records and the like will be studied by the light of that interest, instead of being put aside as dry and unintelligible. Therefore, Sir, with the object of advancing Meteorology by the spread of a knowledge of its principles, we appeal to the Fellows for assistance. We ask them to send copies of any photographs they may take, either to us, or to the Council of this Society—for I take it either course will come in the long-run to much the same thing.

The collection we are making is intended for a variety of purposes. Firstly, of course, as a record of scientific facts; but also as affording the means of study and perhaps the means of teaching also. I am constantly being asked where good lantern slides can be got to illustrate lectures on meteorological phenomena, and I have always to reply that I know of no place where they can be obtained. We hope that this deficiency may be supplied by means of our collection, if only meteorologists will lend us sufficient support.

However, I must not dwell at too great length upon what I may call the popular aspect of our work. I believe it to be of very great importance, but it is most certainly second to the scientific aspect.

We hope that in time we may form a collection which will give a pictorial record of all sorts of meteorological phenomena. But we want something more than that. We want every photograph to be accompanied by a full account of the circumstances under which it was taken, and in the case of

clouds of the method adopted in its production. There are many problems of the first importance which may possibly so be solved. For instance, what are the relations between the various forms of clouds? How are those various forms produced? What relations do they bear to the distribution of barometric pressure? These are only a few specimen queries, none of them have yet been satisfactorily answered. No doubt men like the Rev. W. Clement Ley know a very great deal about clouds, but however complete their knowledge may be they cannot communicate it all to others for want of an adequate system of cloud nomenclature.

One of the first things, then, is to get together as many photographs of clouds as possible. Unfortunately, cloud photography is not easy, so a preliminary task is to find some means of simplifying the art. Heavy clouds, or clouds which stand out dark on a background of an evening sky are easy to take, but the more delicate forms of cirrus (just those about which least is known) are extremely difficult subjects for the ordinary photographer. A short exposure, correctly timed, will give a good result, but the difficulty is to get that correct time.

Various special devices have been described, such as using a slow plate, placing yellow glass in front of the lens, and so forth. We hope that some one will take up each of these methods and give it a thorough trial, such as I have given to a third. This method has been described in theory by Dr. Riggenbach so long ago as November 1888. As his paper is printed in the *Quarterly Journal*[1] of this Society it is not necessary for me to give a long description. When I first made my own apparatus I thought I had made a discovery, as Dr. Riggenbach's paper had escaped my notice, or it may be that my memory was at fault, and I conceived the same notion by what Dr. Carpenter has called "Unconscious Cerebration." This means that such credit as the method deserves must be given to Dr. Riggenbach, and the beautiful specimens of his own handiwork which are displayed in our exhibition are probably results achieved by its means. It consists in placing a mirror of black glass in front of the lens so that the plane of the mirror makes an angle of about 33° with the axis of the lens. It has long been known that some of the blue light of the sky is polarised in a certain plane, while that from a cloud is not. The mirror extinguishes the polarised light and so makes the image of the cloud stand out brightly on a dark background. This is especially the case when the cloud in question is situated about 90° from the sun, and, according to theory, the mirror should be of less and less advantage as the point of view is more and more distant from this position. As a matter of fact, I have found that the position does not greatly affect the efficiency of the mirror, its advantage being apparently due also to other causes. Being a dark mirror, it reduces the whole brilliancy of illumination, so that it becomes comparatively easy to judge the exposure correctly. The pictures of cirrus and other clouds which I show you to-night give a good idea of the value of the method, especially as I cannot lay claim to any particular skill above that of an average amateur.

[1] Vol. XV. p. 16.

Another point which these photographs illustrate is the advantage of taking a series of photographs showing either the rapidity of cloud changes, or the numerous varieties of forms assumed by cirrus clouds in a given part of the sky at intervals of a few minutes. Clouds of all kinds, cirrus, stratus, cumulus, whatever they may be, can be recorded with certainty if a little care and trouble is spent over the development of the negatives and preparation of the prints.

Clouds of course suggest rain and snow, and we hope to receive photographs showing the results of abnormal rains, such as these two records of floods at Bristol, heavy snow drifts, and even the forms of snow crystals themselves. The two slides of snow crystals I show were taken under such conditions that the image on the slide is the same size as the original snow flake. Even glaciers supply an object of great meteorological interest; for it would be most useful to have a series of pictures from a given point of view, showing the changes in the volume of a given ice-stream from year to year, and the alterations in the position of its end.

Among the photographs I have the pleasure of showing upon the screen you may notice one of a part of a solar halo. The original of this was quite invisible to the naked eye, being lost in the dazzling glare of the silvery grey sky.

Hoar frost gives innumerable beautiful objects well worthy of the camera from an artistic point of view, and well worthy of attention from the meteorologist. The photographs on the screen show plainly enough the way in which the crystals arrange themselves around the foliage of a plant, fringing the leaves, forming tassels upon thorns, and generally gathering most thickly on the smallest objects. Many of these things are still unexplained.

But perhaps the most interesting of all Meteorological Photographs are those of lightning. Here again there are many problems to be solved. We have in the possession of the Society a very fine collection of photographs of lightning, and it is indeed these pictures which have demonstrated how desirable it is to have many more. The black flashes I think I have explained. Nevertheless, I should like to see two photographs of the same flash, one black and the other white. The unsolved problems are to be found in the forms of lightning. Most of us are familiar with the broad ribbon-like flashes shown in some photographs, and with the narrow ribbons shown in others. These have been explained as due to a movement of the camera during the existence of a flash; probably many of them are, but I do not feel satisfied that all of them must be so explained.

A few photographs of electric sparks which I throw on the screen will justify this position. Sparks under given conditions tend to repeat the same form again and again, so that there seems no necessity for supposing a series of flashes should not follow similar-shaped, but not identical, paths. Again, under suitable conditions, electric discharges take the form of bright rosy pink or red discharges, each of which consists of some bright sparks, linked together by the pink or red and much less luminous discharge. These pink sparks, as I may be allowed to call them, seem to me to be the precise

analogue to some of the flashes of lightning which yield broad ribbon photographs, multiple flashes, and such pictures as Dr. Hoffert's well-known photograph.

Well, Sir, I feel that I have only given a most meagre outline of a very large subject, but I hope that outline will be enough to explain what the British Association Committee on Meteorological Photography aims at. The success which may attend its labours depends almost entirely upon the assistance of others; but if the Fellows of this Society support us as cordially as the Council, we are certain to reach some results of real and lasting value.

ON THE VARIATIONS OF THE RAINFALL AT CHERRA POONJEE IN THE KHASI HILLS, ASSAM.

By HENRY F. BLANFORD, F.R.S., F.R.Met.Soc.

(Plate VI.)

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Cherra Poonjee, on the southern verge of the Khasi Hills of Assam, overlooking the plains of Sylhet, has long been notorious as having a heavier rainfall than any other known place on the globe. It has already been described at some length by Mr. John Eliot in the *Quarterly Journal* of the Society for January 1882 (Vol. VIII. p. 41); but there is one feature exhibited by the registers which Mr. Eliot did not specially refer to, viz. the apparent falling off of the annual totals of the later as compared with the earlier years, and as this is a matter of some interest, and one to which my attention has long been directed, I have taken some pains to ascertain the circumstances under which the registers were kept in different years, and especially the positions of the rain-gauges. Three of the observers who contributed to these registers, viz. Dr. (now Sir Joseph D.) Hooker, Dr. (now Sir Joseph) Fayrer, and Major (now Colonel) H. H. Godwin Austen have kindly furnished me with the required information as far as regards their own work and that of the late Dr. T. Oldham, and from a fifth, the late Col. McCulloch, I obtained similar information for his contributions to the registers some time before his death. Moreover I have myself twice visited Cherra Poonjee, and have therefore some personal acquaintance with the topography of the place and the relative positions of the houses, now for the most part in ruins, at which the rain-gauges have been situated at different times. These, as far as they are certainly known, are marked on the plan of the station as it existed in 1851, which accompanies this paper. (Plate VI.)

In Mr. Eliot's paper (above referred to) is given a table of the monthly

and annual rainfall of the station for a few months of 1832, and from 1851 to 1880,[1] with the omission of the years 1855 to 1859, 1862 and 1870, for which, as far as I have been able to ascertain, the registers are no longer extant. Some other years are also imperfect. In the appendix to my own Memoir on the rainfall of India, the same table is continued up to 1886, and in that at the conclusion of the present paper it is corrected and continued up to 1888. According to the second of these tables, the mean annual rainfall of Cherra Poonjee is 474 inches; but if we take the average of only the 13 years 1876 to 1888, during which the register has been kept at the missionary station (F on the chart, Plate VI.), and where it is still recorded, it amounts to only 485 inches; whereas on the strength of the earlier registers, it was formerly given in round figures at 600 inches, and is still sometimes so quoted in meteorological treatises and handbooks. As I shall be able to show, a part of this discrepancy is undoubtedly due to a change in the site of the rain-gauge; but a portion is also due to the inclusion of the two years 1860 and 1861, the rainfall of which, according to the returns, reached the enormous figures of 700 and upwards of 900 inches respectively. Of the validity of these last, for reasons to be given presently, I am extremely sceptical. The daily registers of these years have apparently been lost; at all events I have never been able to procure them; and on a comparison of the monthly totals with those of the more authentic returns, I have but little hesitation in rejecting them. But even admitting these registers, the average rainfall of the station has been greatly over-estimated, and really but little exceeds 500 inches. Omitting them, the average of the registers extant up to the end of 1875 amounts to 468 inches, or up to the end of 1869, 504 inches, which is perhaps the most trustworthy.

The earliest published notice of the Cherra Poonjee rainfall of which I have any knowledge, is that for a few months of 1832, by Mr. Cracroft, quoted by Dr. Oldham.[2] In this there is nothing specially calling for remark, and I am unable to say where the rain-gauge was situated. The next notice is one by Lieut. (the late Col. Sir Henry) Yule, published in the 13th volume of the *Journal of the Asiatic Society of Bengal*, and this may be quoted at length, inasmuch as, while the authority is unquestionable, the quantity measured in the month of August 1841 exceeds that of any other single month in our existing records, with the sole and very dubious exception of

[1] I have lately ascertained that, owing to the error of a copyist, the monthly totals of the rainfall of 1869 given in the table at page 51 of Mr. Eliot's paper, and also at page 458 of the Appendix to my own memoir on the rainfall of India (Vol. III. of the *Indian Met. Memoirs*), are very erroneous. Those, however, given in the tables of daily rainfall (pages 46 to 50 of Mr. Eliot's paper) are correct. There is no record of that of the months January to April of that year, nor for December. The totals of the remaining months are:—

May	June	July	August	September	October	November
ins.	ins.	ins.	ins.	ins.	ins.	ins.
104·48	107·20	100·42	123·97	82·70	3·71	0·00

[2] *Geology of the Khasi Hills*, Appendix p. vi.

July 1861. The writer says: "It is with some hesitation that I write it, but the unexceptional mode of measurement, and the many times that I have seen my friend who registered the fall take these remarkable gauges, leave me no room to doubt. In the month of August 1841, during five successive days, 30 inches of rain in the 24 hours fell at Cherra; and the total fall in the month of August was 264 inches, or that there may be no mistake, 22 feet of rain. The gauge was simply a large glass jar having a funnel fitted with projecting eaves, and the water was measured morning and evening with a cylinder 8 inches in depth, of equal diameter with the funnel." Lieut. Yule does not say where the gauge was situated, but there can be little doubt that it was at one of the houses of the old and now deserted station, at one or another of which all the registers were kept up to the end of 1875.

A cursory notice of the rainfall of 1849 and 1850 is given in Dr. Hooker's *Himalayan Journals* (Vol. II. p. 282). The writer says: "Dr. Thomson and I recorded 30 inches in one day and night, and during the seven months of our stay 500 inches fell, so that the total annual fall perhaps greatly exceeded 600 inches or 50 feet, which has been registered in succeeding years. From April 1849 to April 1850, 502 inches (42 feet) fell." He further remarks: "At the Cherra station the distribution of the rain is very local, my gauges, though registering the same amount when placed beside a good one in the station, when removed half-a-mile received a widely different quantity, though the different gauges gave nearly the same amount at the end of the whole month." The house occupied by Drs. Hooker and Thomson was that marked A on the chart.[1] Sir Joseph informs me that his own register was very imperfect, owing to his frequent absence from the station, but that a regular register was kept at the same time and for some years previously by Dr. Mann, the Civil Surgeon, at the house marked B on the chart, the same that was afterwards occupied by Dr. Fayrer. This register unfortunately appears to have been lost. It was not among the records of the Calcutta Medical Office communicated to me some years since. It is not quoted by Dr. Oldham, and I have been unable to learn whether any copy of it exists elsewhere.

The register of the rainfall of 1851 and the greater part of 1852 is given in the Appendix to Dr. T. Oldham's *Report on the Geology of the Khasi Hills*, from which also is copied the chart that illustrates this paper. That of 1851 was registered partly by himself at the house marked C, partly by Dr. Fayrer at the house marked B,[2] and amounted to a total of 551·16 inches. That of the rainy season of 1852 was registered by Dr. Oldham at the house marked D, and that of the earlier and later months by Dr. Fletcher, the site of whose house I do not know.[3] It amounted to 449·68 inches. With respect to the variation of the rainfall within short distances, Dr. Oldham's remarks confirm those of Sir J. Hooker already quoted. He says: "It may

[1] For this identification I am indebted to Sir Joseph Hooker and General Cave.

[2] Identified by Sir Joseph Fayrer and General Cave.

[3] If, as is likely, he occupied the house vacated by his official predecessor, it would be that marked B.

be desirable to notice the extremely local distribution of much of the rain, even within such limited distances as a few hundred yards. A striking instance of this occurred to myself on the 12th October. About 4 o'clock on the afternoon of that day, I was geologising at about a quarter of a mile from the place where my rain-gauge was placed, mist and driving cloud passed over me with a few drops of rain, and continued for about 40 minutes, but scarcely sufficient to wet the light clothes I wore, and not at all such as to compel me to return home; on my return, I was greatly surprised to find that during the same time more than half an inch of rain was indicated by the gauge. At first I doubted the accuracy of this, I fancied that some accident or design had led to this result, but on the most ample and strict inquiry, I found it was not so; and that the rain, not more than 500 yards from where I had experienced only a driving mist, had come down in torrents." And again, "It is perfectly well known to the residents at the station, that some of the houses are more affected by the mist and cloud from the valleys than others, and especially those which are near to the deep valley to the east of the station. Dr. Fayrer's gauge was nearer to this valley than mine (see the map); about half way. Thus the return for September from Dr. Fayrer's table was 70·80 inches, while we had only 66·64 inches. In July Dr. Fayrer's return gave 100·85; ours gave only 96·28."[1]

The returns from November 1852 to December 1854 are taken from a register received by the late Baron Hermann v. Schlagintweit from the Medical Office in Calcutta. It was doubtless kept by the medical officer of the station, probably Dr. Fletcher, and nothing is stated of the position of the gauge. The totals were 524·5 inches in 1853, and 552·58 inches in 1854.

The registers from 1855 to 1859, if ever recorded, have been lost, but some years ago, when all the rainfall returns then extant in the office of the Surgeon-General of Bengal were handed over to the Meteorological Office, they included the two remarkable registers of 1860 and 1861 already referred to, and a very imperfect register for 1862. Of the circumstances under which these were kept nothing is known, but there can be little doubt that the rain-gauges were throughout in some part of the old, and now nearly abandoned, station. They give a far higher rainfall than those of any other years in the table; that of 1860, deficient for the whole of November and December (which, however, are generally rainless months), amounting to 700 inches, and that of 1861, although wanting the month of March (which is scarcely ever rainless), the enormous fall of 905·12 inches, of which 886·14 inches are returned for the month of July alone. Inasmuch as this last exceeds by more than 100 inches the enormous fall of August 1841 (authen-

[1] The gauge used by Dr. Oldham is that known as Fleming's gauge, consisting of a cylindrical tube 3 ft. long, with a float carrying a graduated rod. It was placed in the centre of a small raised plot in front of the house, at an elevation to the top of the funnel of 3 feet 4 inches.

ticated by Lieut. Yule), it might, standing by itself, raise some doubt of its authenticity, and since in no less than seven months of the three years[1] the monthly totals exceed the highest recorded in the corresponding months of any other year, and some others are but slightly surpassed in other years, I think there can be but little hesitation in rejecting the whole of these registers. I feel the more justified in this conclusion, that on comparing these Cherra Poonjee records with those of Sylhet for the same years, I find that the latter exhibit no similar anomalies, except perhaps in April and May 1860; and since Sylhet is situated near the foot of the Khasi Hills, little more than 20 miles distant from Cherra Poonjee, it might certainly be expected to share such remarkable rainfalls as those of the years now under consideration at Cherra.

I have been unable to ascertain the authority for the rainfall of 1863. I believe, however, that like that of the following years up to 1869 inclusive, it was received from officers of the Survey Department, who, at all events from 1864, were engaged in the survey of these and the adjacent hills. Col. H. H. Godwin Austen, who had charge of the party from 1866 to 1869, informs me that in 1864 the record was kept by Mr. N. A. Bellety, in 1865 by Capt. R. V. Riddell, R.E., and from 1866 to 1869 by himself personally or under his supervision. In the last three years the gauge was at the house marked B, and in 1865 and 1866 at that marked C in the chart. For some portions of these years Col. Godwin Austen furnished also a complete meteorological register, the only one, except that of Dr. Oldham, that we possess for Cherra Poonjee. This has been noticed by Mr. Eliot in the paper above referred to in this Journal.

In 1868, Cherra had been abandoned as a military station, and the only occupants left were the officers of the Survey party, Col. McCulloch, a retired officer in the Political Department, with one or two other private residents, and the missionaries, whose establishment lay a mile further to the north-west. At the end of 1869, it was vacated also by the Survey party, and for 1870 there is no register. In 1871, Col. McCulloch (the son of the well-known author of the *Geographical Dictionary*) volunteered his services to the Meteorological Department, and from that year to March 1876, when he removed to Shillong, he kept a regular register at the house in which he lived and which is that marked E on the chart. On leaving the station he made over the rain-gauge to the missionaries, who have since kept the register at the house marked F.

Thus we see that up to March 1876 all the registers, as far as can be ascertained, were kept at one or the other of the little group of houses immediately surrounding the church on the south, all lying within an area measuring less than half-a-mile from east to west, and less than a quarter of a mile from north to south. Indeed most of those given in the table, up to 1869 inclusive, were probably recorded at the house B on the chart; and all from 1871 to March 1876 at the house E. From April 1876 up to the present time the rain-gauge has been at F, a mile further to the north-west.

[1] In October 1860, April, May and July 1861, and January, February and March 1862.

Now on tabulating the rainfall separately for these three sites and periods, we find the following variations of the annual averages.

			Ins.		Ins.
Up to 1869,	8 to 13 years,	chiefly at B	503·92	probable error	±19
1871 „ 1876,	5¼ „	at E	382·93	„	±24
1876 „ 1888,	12¾ „	at F	485·22	„	±12

The periods are evidently insufficient to afford more than a very rough approximation to true averages, but at the same time the discrepancies are too great to be accounted for by the ordinary non-periodic vicissitudes of the rainfall. It is true that the year 1873, which is included in the E registers, was one of remarkably low rainfall in the province of Assam generally, as well as in many other parts of India, indeed the driest on record; the mean rainfall of the province having been 19 per cent. below the general average, and that of Bengal 31 per cent. below it. But that of 1871 was of average amount, and that of the other three years from 4 to 6 per cent. in excess, so that had the rainfall of Cherra Poonjee varied with that of the province generally, the mean of the five years would not be much more than 1 per cent. below the general average. A comparison with the registers of Sylhet and Shillong, the former, as already mentioned, 20 miles to the south, the latter 30 miles to the north of Cherra, leads to a similar result. This is shown by the following table, as far as the existing records admit of:—

Period.	Sylhet. Mean. ins.	Sylhet. Mean var. ins.	Sylhet. Per cent.	Shillong. Mean. ins.	Shillong. Mean var. ins.	Shillong. Per cent.
Up to 1869 ...	145·07	−12·26	−7·8	?	?	?
1871 „ 1875 ...	159·26	+ 1·93	+1·2	81·18	−2·57	−3·1
1876 „ 1888 ...	163·20	+ 5·87	+3·7	84·85	+1·10	+1·3

According to this table, the first period up to 1869 was one of very low average rainfall at Sylhet, but I do not think this result can be implicitly relied on, because during the greater part of this period there was no proper supervision of the registers, and some of the rain-gauges in use may have been defective. For the two latter periods the results are more trustworthy, and they show that both at Sylhet and Shillong the mean of the years 1871 to 1875 was between 4 and 5 per cent. lower than that of the years 1876 to 1888, the mean of the two stations in the former period about 1 per cent. below the general average. So far therefore the great deficiency of the E registers at Cherra Poonjee remains unaccounted for.

Nor do I know of anything in the local circumstances that will help to explain it. The rain-gauges in use at Cherra after 1870 were furnished from my own office in Calcutta, and Col. McCulloch, though not experienced as a physicist, was a man of more than average intellect, and too conscientious an observer to allow of any suspicion of neglect of his registers, though it is possible that he may have been unaware of some unrecognised source of error. There is no such difference in the position of the houses B and E as

to lead one to anticipate a great difference in the averages of the local rainfalls. Col. McCulloch's house E is but a furlong to the north of the house B occupied by Dr. Fayrer (probably Dr. Fletcher) and Col. Godwin Austen. It is nearer the margin of the plateau, and according to Dr. Oldham the nearer this was approached, the heavier was the rainfall. Col. Godwin Austen testifies to the same effect. Nevertheless, I cannot but consider that from some unexplained cause the amounts shown by the E registers were considerably below the real values.

On the other hand, the difference of the average rainfall at the missionaries' station F and the houses B, C, &c. is only such as might be expected from the position of the former, a mile to the north-west of the latter, and screened by a range of hills from the south-west. On this point Col. Godwin Austen writes: "The rainfall was much less towards the native village (half a mile to the north-west of the missionary station), and it was often clear there when raining or dense mist over the plateau."

The final conclusion then at which I arrive as the result of this inquiry is that the rainfall varies very greatly in different parts of the little plateau on which the station of Cherra Poonjee is situated, and the form and position of which are shown on the map that accompanies Mr. Eliot's paper in the 8th volume of the Society's Journal. The average annual fall of the old station around the church is probably a little over 500 inches, being perhaps 5 per cent. greater near the eastern margin of the plateau than at houses about 3 furlongs distant from it. At the missionary station, a mile to the north-west, it is about 70 inches less, and on the other hand it is quite probable that it may be considerably higher further to the south in the direction of the Mausmai precipice; but there is at present no evidence that the average of any part of the plateau is so high as 600 inches, though it may amount to as much in certain wet years.

It is very desirable that further registers be obtained from some of the old sites, or from some still more southerly portion of the plateau, and now that some houses in this direction are occupied by officers connected with the inclined tramway that leads from Cherra to the foot of the hills, this may perhaps be practicable. I understand from Mr. Eliot that he hopes to be able to do this, when the results of the present inquiry are communicated to him.

The following is a table of the monthly rainfall of Cherra, compiled from such registers as have been preserved, corrected up to the end of 1888.

RAINFALL OF CHERRA POONJEE (CORRECTED TO 1888).

Years.	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Totals.	Site of Gauge.
	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	
1832	?	?	?	?	?	?	73·72	52·38	55·30	15·79	?	?	?	?
1841	?	?	?	?	?	?	?	264·00	?	?	?	?	?	?
1851	0·75	3·05	1·30	31·35	114·90	148·53	96·28*	88·54*	66·46*	40·30*	?	?	591·46 ?	B (6 mo.) C (*)
1852	..	1·45	9·90	28·60	49·75	83·25	168·52*	58·45*	49·71*	1·50	1·20	..	452·33	B ? and D (*)
1853	0·60	..	3·45	26·50	44·20	130·85	66·80	108·45	135·15	5·25	3·35	..	524·50	B ?
1854	..	3·59	6·52	33·24	10·95	146·57	141·88	140·76	23·92	31·78	13·37	..	552·58	,, ?
1863	?	..	..	21·80	37·03	105·09	116·23	91·58	70·75	1·20	..	..	443·68 ?	?
1864	0·30	18·60	4·55	22·35	36·09	119·28	138·25	95·90	32·85	19·35	0·60	..	488·12	C ?
1865	..	1·37	2·40	11·53	59·00	139·00	208·40	58·80	20·50	3·10	..	..	504·10	C
1866	0·85	2·88	8·18	?	20·73	94·67	122·26	58·00	38·90	23·34	?	?	?	,,
1867	0·60	1·50	7·50	14·60	?	102·46	130·76	56·92	25·85	10·41	?	?	?	B (monsoon mo.)
1868	?	?	?	?	?	134·95	170·28	82·74	85·74	1·36	?	?	?	,,
1869	?	?	?	?	104·48	107·20	100·42	123·97	82·70	3·71	..	?	?	,,
1871	?	0·91	5·03	20·36	33·33	78·08	73·71	54·69	33·64	21·20	0·50	..	321·45 ?	E
1872	0·51	0·35	11·59	28·95	34·61	103·65	129·05	53·54	101·49	13·72	0·37	..	477·83	,,
1873	0·21	4·14	11·45	17·94	13·36	88·82	71·04	52·71	21·73	0·97	..	0·63	283·00	,,
1874	1·07	4·66	10·97	28·33	96·43	64·27	115·10	45·36	47·96	8·03	0·37	..	422·55	,,
1875	2·77	0·79	6·94	54·35	22·78	134·16	88·09	83·80	14·40	0·50	..	..	408·58	,,
1876	..	1·63	17·57	31·91	53·86	184·80	79·37	65·02	19·43	15·76	..	..	469·35	E (3 mo.) F (9 mo.)
1877	1·16	1·14	11·10	11·76	35·19	45·59	111·07	39·30	120·05	4·87	0·10	1·07	382·40	F
1878	2·05	3·78	10·07	20·24	19·03	136·01	151·77	118·61	76·68	8·33	5·37	..	551·94	,,
1879	..	0·78	0·38	10·86	84·69	134·80	106·89	90·16	45·24	11·57	..	1·75	487·12	,,
1880	2·03	4·55	50·30	56·08	24·68	121·73	95·27	119·92	24·82	8·12	0·14	0·68	508·32	,,
1881	..	0·57	6·29	27·37	50·20	110·83	66·25	78·53	71·04	3·16	1·35	0·02	415·61	,,
1882	0·01	4·63	15·59	22·60	37·51	104·49	34·49	92·42	44·91	33·87	0·68	..	391·20	,,
1883	1·28	..	4·43	14·39	67·32	84·85	67·49	65·99	56·29	6·32	..	3·24	371·60	,,
1884	0·20	3·02	15·53	19·73	56·28	45·80	94·36	44·07	11·40	26·09	1·90	..	318·38	,,
1885	0·03	0·81	8·62	24·12	25·81	85·03	107·28	55·73	127·19	6·56	1·25	0·03	442·46	,,
1886	..	1·79	8·26	41·11	33·12	93·91	105·88	118·18	56·63	3·75	..	0·05	462·68	,,
1887	4·28	..	20·81	28·02	47·70	192·23	38·03	57·35	48·71	3·35	..	..	440·48	,,
1888	1·99	2·01	20·47	35·49	69·72	107·86	72·19	71·46	20·22	16·52	0·31	..	418·24	,,

DISCUSSION.

Mr. TRIPP said that the Society was indebted to the author for bringing forward the subject, but unfortunately the paper was not complete as to existing records, as neither the figures for 1860-61 contained in Mr. Eliot's paper, *Quarterly Journal*, Vol. VIII., p. 41, also in the author's *Indian Meteorological Memoirs*, nor those for March to December 1859, giving a total of 618·46 ins., published by Mr. Glaisher for the Indian Army Medical Department, were included. He thought that these should have been included, with a warning, if necessary, that the reliability was doubted by the author. The paper was interesting, as leading to a discussion of the grounds on which records may or may not be accepted. It is a very difficult task to prove that records are wrong after they are taken. Meteorology may be called a science of surprises, and records should not be lightly rejected. The existing records for 1860-61 were condemned by the author as incorrect on the ground of their extraordinary height. It is not quite clear whether this is the only objection to them, at all events they were greatly borne out by surrounding records. He (Mr. Tripp) had examined the records of all stations given in *Indian Meteorological Memoirs*, Vol. III., East of the 88th meridian and North of the 22nd parallel, with the following result:—

First, 1860, 10 out of 17 contiguous stations above mean, and 12 the wettest recorded.

Second, 1861, 15 out of 18 contiguous stations above mean, and 4 the wettest recorded.

Third, 1873, the driest year at Cherra Poonjee, below mean at 18 out of 19 contiguous stations, and at 6 was the driest recorded, being above the mean at one only. This proved the general agreement of records at Cherra Poonjee and contiguous stations. The records for 1860-61 are known to be very generally wanting in Indian records. From the diagrams which he (Mr. Tripp) had made it appeared that there was nothing abnormal in the rainfall for 1860, except that all the months were above the mean. The total was about 700 ins. In 1861 all the months except August were all above the mean, the most extraordinary feature being that the fall for July was about 200 ins. above the figure at which, judging from the usual form of the diagrams of the other stations, it should stand. There was nothing like it at any contiguous station, although July is in many cases the wettest month. The total for the year was about 905 ins. Was there anything in the original records to indicate that July should be 136 ins. instead of 336 ins., or some 200 ins. lower? If, however, a mean of about 500 ins. is admitted, considerable variations above and below that figure must be looked for. Unfortunately, there is no other station with nearly the same amount of rainfall with which to compare Cherra Poonjee. Stations, however, in exposed situations as seaports, and mountains as St. Bernard, have usually the greatest variation. Out of some 70 stations recently analysed, some 10 gave over 187 per cent., the mean being 100, the mean of the 10 maxima being 116, and of the minima 51. This would give for Cherra Poonjee, maximum 1,080, mean 500, and minimun 255.

Taking 4 Indian records included in the above 70 with the highest variations the means are 179, 100, and 45, giving for Cherra Poonjee 895, 500 and 225. Even the ordinary figures of 1½ times the mean would give the mean 750. There is consequently nothing improbable in a maximum of over 990 ins. with a mean of 500.

Some Remarkable Features in the Winter of 1890-91.

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The details relating to the long frost which prevailed over England during the earlier half of last winter were so fully and so ably dealt with in a paper read before the Society at the February Meeting that I propose saying very little on the present occasion about the temperature of the season. There are, however, one or two points of interest which seem to demand some slight passing notice. It is, for example, not a little remarkable that a winter which opened with so severe and prolonged a frost should have ended with a short spell of unusual warmth, the temperatures registered at the close of February being, in many parts of the country, quite exceptional for the time of year. Maximum readings exceeding 60° were of common occurrence over the entire Kingdom, and in many parts of England the thermometer on February 27th and 28th rose above 65°. The night readings were at the same time considerably below the freezing point, and the daily range of temperature was therefore excessively large, the difference between the maximum and minimum readings being in many instances as much as 40°. Taken in conjunction with a still longer period of mild weather which prevailed during the close of January and the beginning of February, the unusual warmth experienced at the close of the season had a very perceptible effect in raising the mean temperature of the winter, so that when we come to sum up the results for the whole period we find that in many parts of England the winter of 1890-91—severe though it was—was decidedly less cold than that of 1878-79.

The peculiarities in temperature observed during the period were, however, by no means the only features of interest in a very remarkable season. A cold winter is usually, though not invariably, brought about by an undue prevalence of anticyclonic conditions, and there was no season within recent years in which this characteristic was more strongly marked than in that of 1890-91.

During the frost which lasted from the close of November to about January 21st or 22nd, the weather over England was affected mainly by a huge anticyclonic system which extended over the Continent from Russia. Occasionally in the rear of "V-shaped" depressions, which advanced over the west coasts of our Islands, smaller anticyclones drifted across the United Kingdom from the westward or north-westward, the systems ultimately becoming united with the European high-pressure area. In February the Russian anticyclone gave way, but a new one advanced over France and Germany from the south-westward, and as the borders of this system extended northwards over a considerable portion of our Islands, the conditions over England remained, for

the most part, under the influence of high barometer readings. As a result of the very marked persistence of anticyclonic weather it appears that the mean pressure over the British Isles was above the average in all three of the winter months. In December 1890 the excess was slight in the southern parts of the United Kingdom, but large (0·8 in. or more) in the north and east of Scotland. In January 1891 the difference from the mean amounted to between 0·10 and 0·15 in. over Great Britain, but to 0·20 in. in the south of Ireland. The most remarkable difference was, however, in February, when the mean pressure over the United Kingdom was from 0·8 to 0·5 in. above the average in all districts, the greatest excess being found over England and the east of Ireland. At Kew Observatory, the continuous records for which have been kindly placed at my disposal by the Meteorological Council, the mean pressure for February, derived from the hourly readings of the barograph, was no less than 30·474 ins. or 0·479 in. in excess of the average for the 20 years 1871-90, and 0·087 in. higher than in any month of the same extended period.

A comparison between the conditions which prevailed last winter, and the average barometrical pressure over the United Kingdom, may readily be instituted from Maps 1 and 2 (p. 158), Map 1 showing the mean pressure for the whole of the season 1890-91, and Map 2 the average pressure as deduced from the 15 years' observations 1871-85. The values are in all cases derived from observations taken at 8 a.m. As regards the general distribution, it will be seen that over the northern parts of our Islands there was no material difference between the actual state of affairs experienced last winter and its average. Over England, however, we see that in place of a moderate south-westerly gradient there was a decided anticyclonic area, and a ready explanation is therefore afforded of the marked difference which existed between the weather over our northern districts and that experienced over the eastern, central, and southern counties. Turning, however, from an examination of the general distribution of pressure to the actual values, we find a wide difference between the two maps, the lowest isobar in Map 1 being of a higher value than any line shown on Map 2. Taking the winter as a whole the mean pressure was, in fact, from 0·25 to 0·30 in. above the average.

The excessive height of the barometer, as experienced over the south-east of England, is illustrated very clearly by Table I., which has been compiled from the Kew Records. The table gives for each of the 21 winters 1870-71 to 1890-91, firstly, the mean pressure; secondly, the highest reading observed during the season; and finally, the extreme range. The values have in all cases been reduced to the mean sea level.

The table shows that at Kew the mean pressure of the entire winter was nearly a quarter of an inch above the average, the only season at all approaching so high a mean being that of 1881-82, when the value was 0·018 in. lower than in 1890-91. The absolute maximum pressure (30·74 ins.) agreed fairly well with the average, and it may here be noticed that over England the barometer did not rise so high last winter as in the western parts of the Kingdom. Over Ireland the readings on January 14th were nearly all

TABLE I.

BAROMETRICAL PRESSURE AT THE KEW OBSERVATORY DURING EACH WINTER FROM 1870–71 TO 1890–91.

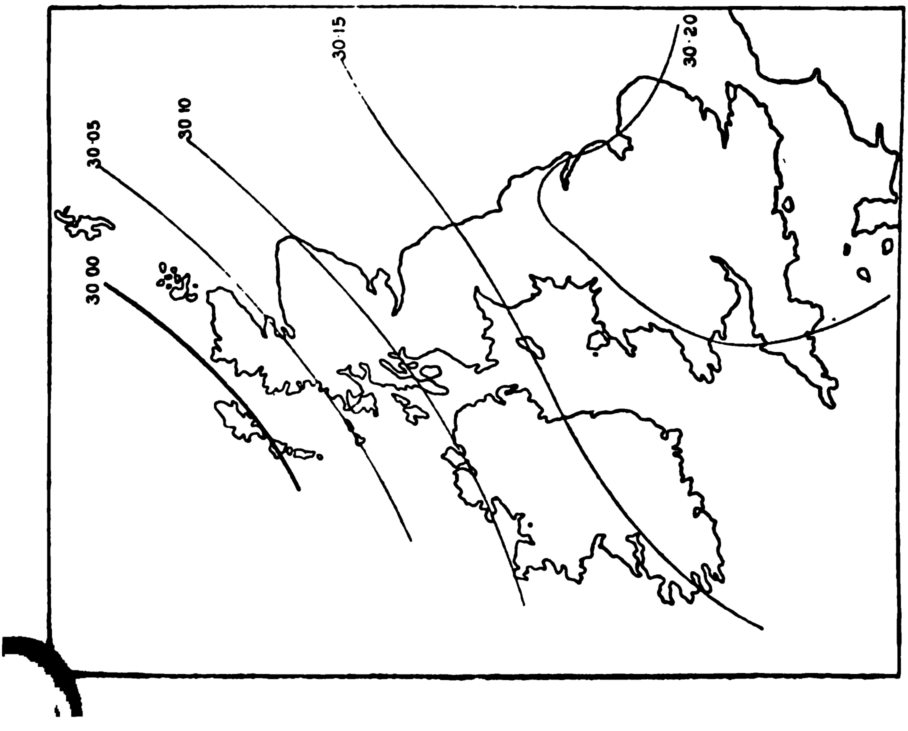
	1870–71.	1871–72.	1872–73.	1873–74.	1874–75.	1875–76.	1876–77.	1877–78.
	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.
Mean Pressure	29·937	29·865	29·820	30·144	29·935	30·080	29·762	30·165
Highest Barometer Reading	30·67	30·54	30·83	30·68	30·69	30·68	30·68	30·70
Lowest ,,	28·88	28·34	28·47	28·97	28·61	29·17	28·38	29·14
Extreme Range of Pressure	1·79	2·20	2·36	1·71	2·08	1·51	2·30	1·56

	1878–79.	1879–80.	1880–81.	1881–82.	1882–83.	1883–84.	1884–85.	1885–86.
	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.
Mean Pressure	29·769	30·176	29·897	30·208	29·893	30·068	29·841	30·012
Highest Barometer Reading	30·46	30·82	30·68	30·98	30·86	30·67	30·43	30·76
Lowest ,,	28·83	28·83	28·87	28·80	28·94	28·54	28·85	29·01
Extreme Range of Pressure	1·63	1·99	1·81	2·18	1·92	2·13	1·58	1·75

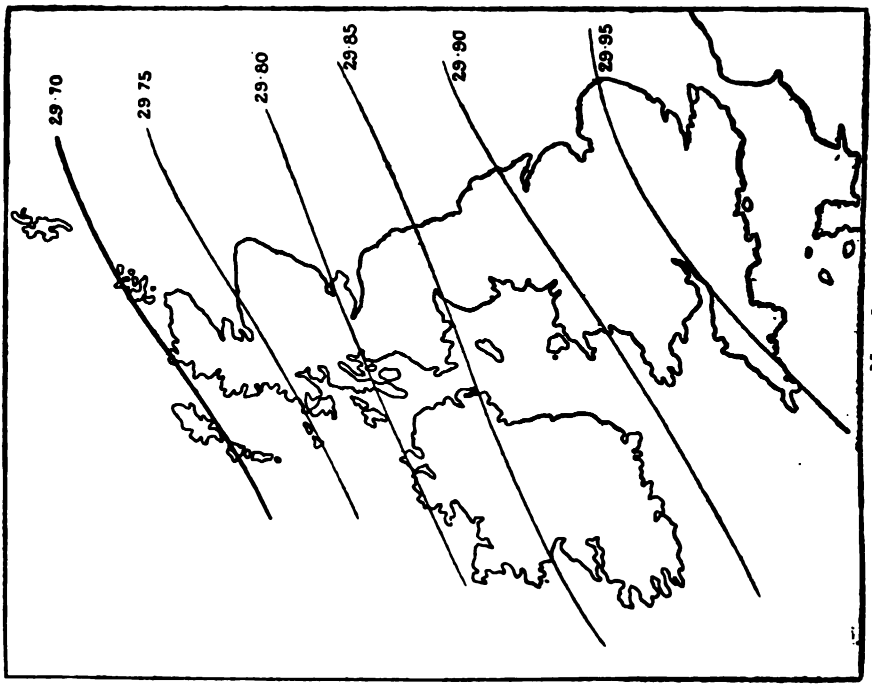
	1886–87.	1887–88.	1888–89.	1889–90.	Mean for the 20 Winters, 1870–71 to 1889–90.	1890–91.
	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.
Mean Pressure............	30·022	30·030	30·039	30·122	29·989	30·226
Highest Barometer Reading	30·76	30·74	30·75	30·72	30·71	30·74
Lowest ,,	28·31	29·25	28·99	28·68	28·79	29·23
Extreme Range of Pressure	2·45	1·49	1·76	2·04	1·92	1·51

above 30·8 ins. and at Belmullet the barometer rose to 30·97 ins. The absolute minimum observed during the winter at Kew (29·23 ins.) was, however, greatly in excess of the average, there being only four winters of the previous 20 in which the barometer failed to go below 29·0 ins. In 1887-88 the absolute minimum was 29·25 ins., or a trifle higher than that of last winter. Owing to the absence of any very low readings the extreme range at Kew was very small, the actual value, 1·51 in., being about four-tenths of an inch short of the average. In 1875-76 the range was equally small, and in 1887-88 it was even a trifle smaller, but in every other winter of the past 20 years it was considerably greater, the highest value of all being in 1886-87, when, in consequence of a very low reading on December 9th, the extreme range amounted to no less than 2·45 ins.

The effect of so constant a prevalence of anticyclonic conditions upon temperature has been dealt with in Mr. C. Harding's paper, to which I have already referred. Its influence upon the winds, the weather, and the rainfall of the winter were no less marked, and are deserving of special notice. Firstly, as regards the wind, we find that over the United Kingdom generally the winter was unusually quiet. Even in the extreme west and north, where the weather was



MAP 1.
Distribution of Mean Pressure in the Winter of 1890-91.



MAP. 2.
Average Winter Distribution of Mean Pressure.

luenced from time to time by low pressure systems which advanced from e Atlantic, the gales experienced were neither frequent nor severe, while over ngland there was an almost entire absence of the ordinary winter storms. Table II., which has been compiled from observations given in the *Daily Veather Report*, gives for the past season, and also for the previous 20 nters, the percentage of wind experienced in London from each of the eight incipal points of the compass, and also the percentage of calms, together th the number of gales and severe gales recorded. The definition of a gale s been taken to mean a wind blowing with at least force 8 of the Beaufort ale, and of a severe gale, as a wind of force 10 or more, the latter occaons being, of course, included in the former. Although prepared for the etropolis only, there can be little doubt that the figures represent with erable accuracy the conditions which prevailed over the Midlands and the and parts of our south-eastern counties generally.

TABLE II.

ERCENTAGE OF WINDS FROM VARIOUS DIRECTIONS EXPERIENCED IN LONDON DURING EACH WINTER, FROM 1870–71 TO 1890–91.

	1870–71.	1871–72.	1872–73.	1873–74.	1874–75.	1875–76.	1876–77.	1877–78.	1878–79.	1879–80.	1880–81.
ercentage of Winds from N..	8	9	8	2	5	7	4	6	8	4	7
,, ,, NE	20	3	5	4	9	12	1	8	13	7	13
,, ,, E	19	1	8	2	13	6	5	1	16	6	9
,, ,, SE	2	6	8	3	6	3	6	5	7	8	4
,, ,, S	4	18	16	15	15	11	28	15	10	18	12
,, ,, SW	19	35	29	34	16	30	20	27	17	24	16
,, ,, W	21	17	8	20	12	16	22	21	13	11	12
,, ,, NW	4	3	8	7	12	2	4	5	10	9	15
,, of Calms	3	8	10	13	12	13	10	12	6	13	12
umber of Gales	6	8	7	6	4	2	13	3	8	8	6
,, Severe Gales	1	2	1	0	0	0	1	0	2	0	2

	1881–82	1882–83.	1883–84.	1884–85.	1885–86.	1886–87.	1887–88.	1888–89.	1889–90.	Means for the 20 Winters, 1870–71 to 1889–90.	1890–91.
ercentage of Wind from N...	3	1	2	6	7	3	11	12	6	6·0	8
,, ,, NE	1	3	4	8	11	8	16	9	7	8·1	10
,, ,, E	3	6	5	11	13	6	10	2	17	7·9	14
,, ,, SE	10	19	7	14	3	8	2	8	9	6·9	7
,, ,, S	23	18	19	26	14	19	12	14	18	16·3	7
,, ,, SW	28	19	20	20	18	16	13	16	17	21·7	14
,, ,, W	10	21	25	10	12	17	21	16	13	15·9	10
,, ,, NW	6	6	10	2	8	10	13	9	7	7·5	8
,, of Calms	16	7	8	3	14	13	2	14	6	9·7	22
umber of Gales..........	7	11	11	13	3	5	5	5	8	7·0	2
,, Severe Gales ..	2	3	4	0	0	1	0	1	0	1·0	0

The influence of repeated anticyclonic weather during last winter is shown very forcibly in the last column of the table, and especially by the very high percentage of calms in London, the actual value (22 per cent.) being more than double the average, and considerably higher than in any other winter of the past 20 years. The number of gales experienced in the Metropolis was only 2 as against an average of 7, and of severe gales there were absolutely none. The weather over this part of the country was, in fact, less stormy than any we have had since the winter of 1875-76, when the number of gales was equally small. In the seasons both of 1876-77 and of 1884-85 there were in London six times as many gales as there were in 1890-91. The prevalence of calm weather is, however, not the only interesting feature shown in the table. From an examination of the proportion of winds experienced from various points of the compass we see that in comparison with the average there was a very large falling off in the percentage of winds from between South and West, and a decided increase in the percentage of winds from between North and East. Taking the points from between South-east and West as representing the equatorial, or mild winds, we find that the total percentage during last winter was only 38, the average for the previous 20 seasons being 61. Taking, on the other hand, the points between North-west and East, as representing the polar or cold winds, we find that the total percentage was 40, or 10 more than the average for the previous 20 years. Summing up, therefore, the state of the wind as experienced last winter in London, we find that when it was not absolutely calm, there was an undue prevalence of breezes from some cold quarter. The percentage of winds from the Southward did not amount to one half of the average.

The anticyclonic conditions which prevailed over England so constantly throughout the winter were accompanied, as one would naturally expect, by frequent fogs, more particularly over the inland districts, and most especially of all in the neighbourhood of London, where the gloominess of the weather caused many ebullitions of temper. In matters relating to the weather public opinion more often than not goes widely astray, but in ascribing to the past winter the character of being one of the foggiest ever experienced, the popular voice was singularly accurate, as the following figures will show. Table III. gives for the whole of the past 20 winters the number of days on which fog was reported in the metropolis, together with the average for the entire period, and the actual number experienced in 1890-91. It should be remarked that in preparing the table no account has been taken either of the density or length of duration of the fog.

It will be seen that not only was the prevalence of foggy weather in London greater last winter than in any of the previous 20 seasons, but that it amounted to no less than twice the average. The nearest approach to so foggy a winter was in 1879-80, when the number of days was 48, or seven less than that recorded during the period under discussion. In no other season was the number anything like so great as it was last winter, and in three of the seasons quoted the amount of fog was less than one quarter of that experienced in 1890-91. By grouping the 20 seasons given in the

TABLE III.

NUMBER OF DAYS OF FOG IN LONDON DURING EACH WINTER, FROM 1870–71 TO 1890–91.

Winter.	No. of Days of Fog.	Winter.	No. of Days of Fog.	Winter.	No. of Days of Fog.	Winter.	No. of Days of Fog.
1870–71	11	1875–76	22	1880–81	32	1885–86	33
1871–72	10	1876–77	9	1881–82	31	1886–87	39
1872–73	24	1877–78	22	1882–83	32	1887–88	20
1873–74	31	1878–79	23	1883–84	18	1888–89	32
1874–75	17	1879–80	43	1884–85	18	1889–90	32

Average Number of Days of Fog during the Winter 25
Actual Number experienced in 1890–91 50

above table into lustra, an interesting result is brought to light. In the first lustrum the mean number of days of fog was only 19, but in the second it had increased to 24, in the third to 26, and in the fourth to 31. The growth of fog in London within recent years is therefore not merely a matter of speculation but one of dry fact.

The precipitation which occurred over England, and of which we shall have occasion to speak more fully later on, was largely in the form of snow, and in London the number of days on which this was recorded amounted to 22, the average number for the previous 20 winters being only 12.

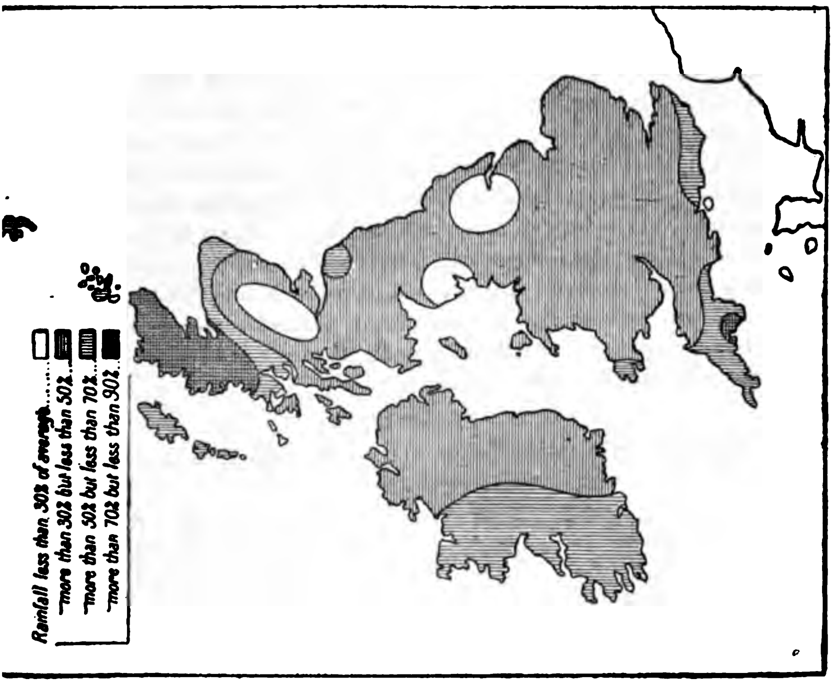
As regards the prevalence of bright sunshine, it appears that while December was upon the whole a gloomy month, January and February had considerably more than their average amount, the last mentioned month being especially sunny at the coast stations. At Jersey the percentage of the possible duration amounted in February to no less than 60, which is probably the highest record for a winter month. The last week in Jersey gave even 89 per cent. In the more central parts of London December was absolutely sunless, and even at Greenwich the total amount registered was only 2½ hours. In January and February, however, a vast improvement in the weather took place, so that when we come to consider the winter as a whole, we find that at Greenwich the number of hours of bright sunshine recorded was considerably in excess of the average for the previous 14 years.

In dealing with the remaining element in the weather of the past winter, viz. the question of rainfall, one is fettered to a great extent by the exigences of time and space. A separate paper, and a fairly lengthy one too, might easily have been prepared on this subject alone, but as there seemed to be no prospect of the question being adequately discussed, I have resolved to devote to it at least a superficial notice. In December the aggregate amount of rain was less than an inch in all parts of England, with the exception of the south-western and extreme northern counties, as well as in many of the central parts of Scotland, while in isolated parts of the same localities it amounted to less than half an inch. The amount was in fact considerably less than the average in all districts excepting the south coasts of Devon and

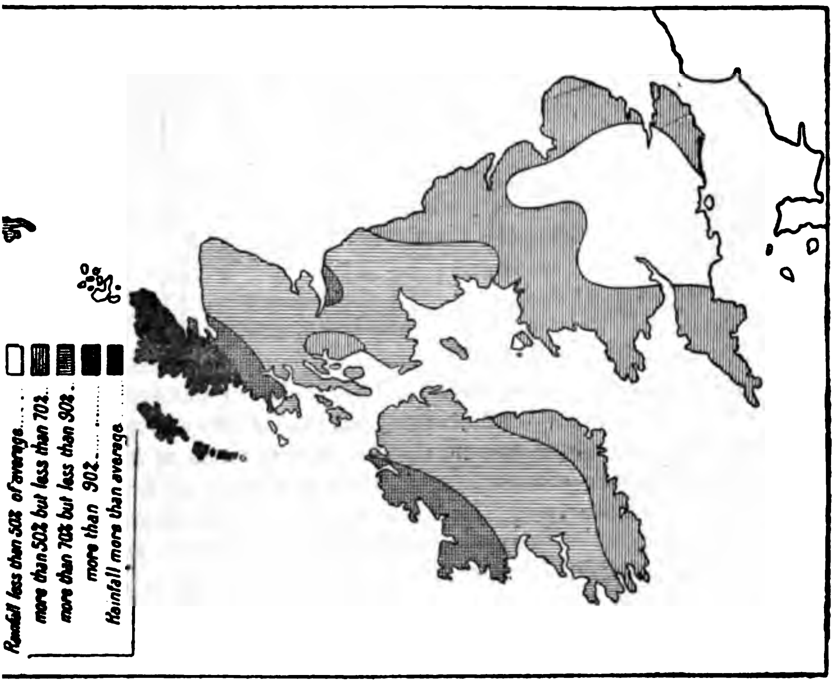
Cornwall, where, owing to heavy falls which occurred on the 5th and 18th, there was no great divergence from the normal. In January the rainfall was far more abundant than in December, but the amount over the country generally was again much less than the average, the deficiency being most marked in the south-east of Scotland and the north-east of England. At Leith the January rainfall was only 0·34 in., or about one sixth of the normal. The absence of rain in the months of December and January was, however, quite insignificant as compared with the remarkable drought of February. Over nearly the whole of England the total amount of rain in the last-mentioned period was less than a tenth of an inch, the only districts in which this quantity was exceeded being small and isolated portions of our north-eastern, eastern, and south-eastern counties (and even in these localities the aggregate fall was made up largely of water yielded by dew and fog), and the counties of Cumberland, Westmoreland, and Lancashire, where an appreciable quantity of genuine rain fell during the early part of the month. In the neighbourhood of Dublin also the total amount was as small as it was over the greater part of England, but further to the westward, as well as in Wales and the eastern parts of Scotland, it increased to between one tenth and one half of an inch, while in the north of Scotland, it was in excess of the average. Taking the United Kingdom as a whole the month was in all probability the driest February ever experienced, and in many parts of England it was also the driest month on record, the aggregate fall in some places being absolutely *nil*. Had the rainfall of February been of a fairly average character, the winter, as experienced over England, would still have been a dry one, but the drought of the latter part of the season served to render it one of the driest, if not the very driest, of which we have any record.

The marked deficiency of rain which prevailed during the winter is shown very clearly in Map 3, which gives in percentage form the difference between the amount recorded in 1890-91 and the average of the 20 years 1866-85. The information contained on the Map is compiled solely from the 75 stations given in the *Weekly Weather Report* of the Meteorological Office, and presents us therefore with no more than a general view of the actual conditions. It is quite possible that when reports are received from a large number of stations, such as are included in Mr. Symons's splendid organisation, some of the features shown in the map may be slightly modified, but it is not likely that the general condition of things will be materially altered.

Map 3 shows, first of all, that over by far the greater part of England and Wales, with the eastern half of Ireland, and the eastern, central, and southern parts of Scotland, the aggregate rainfall of the winter was less than half the average, the only English localities in which this proportion was exceeded being the south-western and extreme southern coasts. In portions of Lancashire, our north-eastern counties and the central parts of Scotland, the amount was less than 30 per cent. of the average, the smallest aggregate of which I have at present any knowledge being at Blackpool, where the winter rains did not amount to more than one fourth of the normal. On the south and south-west coasts of England, the western half of Ireland, and portions of central and north-



MAP 3.
Rainfall over the British Islands during the Winter of 1890–91.



MAP 4.
Rainfall over the British Islands during the six months September 1890 to February 1891.

eastern Scotland, the proportion varied between 50 and 70 per cent. of the average, while in the north of Scotland (though not in the Shetlands and Hebrides) the percentage ranged between 70 and 90. In London the winter was not quite so dry as that of 1873-74, but there can be little doubt that, taking England as a whole, it was the driest we have had for many years past.

Some of the more distinctive features in the London rainfall of last winter as compared with that experienced in the seasons of previous years are given in Table IV., which has been compiled from the observations given in the *Daily Weather Report*. The table shows not only the actual amount of rain in each winter, the number of rainy days, and the maximum fall in 24 hours, but, in order to see how the rain fell, I have picked out the number of days on which the fall exceeded 1·0 in., 0·5. in. or 0·25 in. We are therefore enabled to see whether the wetness of any particular season was due to one or two excessively large falls, to a moderate number of smaller ones, or to a larger number of still smaller amounts.

TABLE IV.

RAINFALL IN LONDON DURING EACH WINTER, FROM 1870–71 TO 1890–91.

	1870–71.	1871–72.	1872–73.	1873–74.	1874–75.	1875–76.	1876–77.	1877–78.	1878–79.	1879–80.	1880–81.
	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.
Total Rainfall	6·16	5·63	8·11	2·50	6·12	3·90	12·30	3·81	8·13	3·21	7·04
Number of Rainy Days	55	53	54	31	45	47	68	45	55	32	48
Greatest Fall in 24 hours ..	0·58	0·50	0·60	0·74	0·55	0·41	1·24	0·52	1·15	0·47	0·56
No. of Falls exceeding 1·00 in.	0	0	0	0	0	0	1	0	1	0	0
„ „ 0·50 in.	1	0	2	1	1	0	5	1	4	0	1
„ „ 0·25 in.	7	7	10	2	9	2	15	3	7	2	11

	1881–82.	1882–83.	1883–84.	1884–85.	1885–86.	1886–87.	1887–88.	1888–89.	1889–90.	Means for the 20 Winters, 1870–71 to 1889–90.	1890–91.
	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.
Total Rainfall	5·12	7·27	3·63	6·08	5·28	6·56	3·56	4·34	4·76	5·68	2·57
Number of Rainy Days ..	32	56	40	50	42	39	37	45	45	46	30
Greatest Fall in 24 hours	0·60	0·63	0·40	0·58	0·36	1·82	0·33	0·51	0·54	0·65	0·31
No. of Falls excdng. 1·00 in.	0	0	0	0	0	1	0	0	0	0·2	0
„ „ 0·50 in.	1	3	0	1	0	2	0	1	1	1·3	0
„ „ 0·25 in.	7	9	3	7	6	7	3	3	3	6·2	2

The table shows, first of all, that in London the aggregate rainfall of last winter was the smallest recorded since 1873-74, while the number of rainy days was less than in any of the previous 20 winters. In the very wet winter of 1876-77 the total rainfall was nearly five times as much as it was last season, while the number of rainy days was more than twice as large. The maximum rainfall in any one day (registered last winter on January 30th) was also smaller than in any of the previous 20 seasons. The entire absence of any daily falls exceeding 1·0 in. and 0·50 in. has had a parallel in more than one recent winter, but there has been no instance since 1879-80 of so small a number of days with a rainfall exceeding only 0·25 in.

It must not be forgotten, however, that the deficiency of rain was by no means confined to the winter months. With the exception of the extreme northern and north-western portions of the Kingdom, where heavy rains fell during October and November, the autumn of last year was also unusually dry, this being more especially the case over the eastern, central, and southern parts of England, where the aggregate amount for the season was in many instances less than half the normal. As an illustration of the remarkably dry period through which we have recently passed I have prepared another map (Map 4), showing again in percentages the difference between the amount of rain actually experienced during the six months ending with February 1891 and the average for a similar period in the 20 years 1866-85. Here, again, the values employed are those given in the *Weekly Weather Report*, so that the results must be taken only in a general sense.

When we consider the length of time over which they extend, the results shown by the Map 4 are very striking. Over nearly all the midland and most of the southern counties of England the rainfall of the entire six months amounted to less than half the average, the lowest percentages of all being 42 at Strathfield Turgiss, 43 at Oxford, Cambridge, and Hurst Castle, and 44 at Hereford, and in London. Over nearly the whole of the remainder of England and Wales, and also in the south-east of Ireland, the aggregate for the six months was less than 70 per cent. of the average, while over a considerable part of Scotland, with the north of England and the central parts of Ireland, it varied between 70 and 90 per cent. In the north-west of Ireland the proportion of rain was more than 90 per cent., while in the north of Scotland, including the Hebrides, it was in excess of the average. In London the autumn and winter months were as a whole the driest on record, and a similar remark applies to Oxford. In the latter case, the records to which I have been able to gain access do not extend further back than 1851, but in the former case the comparison has been made with Mr. G. Dines' *Table of Rainfall for the London District*, which commences in 1813.

It will be seen, in conclusion, that, irrespective of the prolonged frost, the season under discussion was characterised by numerous features which distinguished it from any other winter of recent years. Almost every element in the weather was influenced to an abnormal degree by the remarkable prevalence of high barometrical pressure, and if we were called upon to define the season of 1890-91, we should have little hesitation in giving it the name of the "Anticyclonic" winter.

DISCUSSION.

Mr. Bayard said that Mr. Brodie's paper was a very good illustration of the generally known fact that high barometric pressure in the winter months gave calm weather, fogs, and very little precipitation. He did not quite understand how Mr. Wallis had obtained his figures of probable occurrence of a total monthly rainfall not exceeding 0·25 in. (p. 174), as he did not know it was allowable to add together the number of years over which records extended for each station, and treat them as an aggregate quantity, which Mr. Wallis appeared to have done in compiling his figures of monthly frequency. For instance, it was stated that a rainfall not exceeding 0·25 in. would probably only occur in the month of Novem-

ber once in 728 years, a statement which might lead one to suppose that rainfall records existed as far back as the year 1163, which it was well known they did not. In fact, the longest record quoted by Mr. Wallis did not date earlier than 1814.

Mr. Tripp said that he agreed with the remarks of Mr. Bayard as to the table referred to by him. As regarded Mr. Brodie's paper, he noticed that M. A. Lancaster had stated that a cold winter produced a wet summer. Mr. Stow's paper (p. 176) seemed to rather support this, for the winter of 1878-9, which was cited as being very severe, was followed by one of the wettest summers on record.

Mr. M. Jackson said that February was certainly distinguished for lack of rainfall, but it was also remarkable for the prevalence of fog. At Ramsgate, where he had observed for 30 years, the average number of foggy days in the year was only three, but during last February 12 days of almost continuous fog were recorded. The deficiency of rainfall over the country for several months past was very great. At Tunbridge 2·60 ins. was measured during January, but the greater part of this rainfall consisted of melted snow, most of which flowed into the River Medway, causing serious floods, the surface of the ground being frozen, and so preventing any water percolating through the earth. He feared many localities, which depended upon underground water for their supply, would suffer considerably from drought during the summer months.

Mr. C. Harding said that he had made a comparison between Tables I. and IV., in Mr. Brodie's paper, and had found that when the barometric pressure was below the average the rainfall was above the average, the only exceptions being 1871-2 and 1886-7. He had also examined Hoffmeyer's Charts in order to ascertain whether the same conditions prevailed over the Atlantic when severe weather was experienced over the British Isles, but had found that the distribution of pressure and general conditions were very dissimilar. For instance, in 1881, when very intense frost prevailed over our Islands during January, the conditions prevailing over the Atlantic were in no way similar to those which existed during the winter of 1890-91. Regarding the prolonged character of the cold weather during the past winter, he believed that, supposing that the months of April and May of the present year proved to be of average temperature, the mean temperature of the period, September 1890 to May 1891, would not be so low by about 2° as was that of the similar period in 1887-8, the mean of which was 42°. A study of the charts issued by the Hydrographic Office of the United States shows that the North-east Trade Wind was completely reversed, while in a paper recently read before a French Scientific Society it was stated that the rainfall during February in Algeria had been exceedingly heavy, so that it had not been possible to sow any seeds. There had been less fog than usual in the Atlantic during the past winter, but in the British Islands considerably more fog had prevailed than was generally experienced. Icebergs, too, had been more frequently encountered in the Atlantic recently than was generally the case. The distribution of isobars over England did not give any clue as to the cause of the severe cold experienced during last winter, and it was necessary to greatly extend the area of inquiry in order to fully investigate the cause of such severe seasons as that described in Mr. Brodie's paper.

Mr. Southall said that he wished that the period covered by Mr. Brodie's paper had been extended, as he considered the months of December, January, and February formed a rather arbitrary winter. In the neighbourhood of Ross the drought had now extended over 21 months. He thought it was not possible to forecast the character of the coming summer, and showed that the supposition that a severe winter was usually followed by a wet summer was incorrect.

Mr. Brodie, in reply to Mr. Harding, said that from an examination of the distribution of mean pressure it is clear that the trend of the isobars over England during the past winter was distinctly anticyclonic, so that a very ready explanation was afforded of the intense cold which prevailed in that country. Over Ireland and Scotland the isobars had, on the other hand, a distinct cyclonic tendency, and as a matter of fact the frost in those countries was comparatively slight. With regard to Mr. Southall's objection, the months of December to February were commonly taken to represent the winter, and if the year were to be divided into four seasons of equal length no other definition was possible. A long experience had fully convinced him that the character of any particular season afforded no reliable guide as to the weather which might follow.

Mr. WALLIS, in reply, said that the figures to which Mr. Bayard took exception were qualified by the expression, "Accepting the results given by the table," but although the 728 years were not consecutive they were the best available, and gave a long mean. He believed that though the values could not be considered as exact, they gave a close approximation to the relative frequency of such a small rainfall in the different months of the year.

THE RAINFALL OF FEBRUARY 1891.

BY H. SOWERBY WALLIS, F.R.Met.Soc.

[Received April 1st.—Read April 15th, 1891.]

RAINFALL being expressed in figures, my paper is essentially a collection of tables, and letterpress is needed only to point out their salient features. I have put in rather full tables as evidence of the facts, and have made notes of what appear to me the most important results.

I have prepared a Table[1] which contains returns from 521 stations, being practically all that I could obtain, excepting a few monthly records from gauges in Wales and the Lake district, these gauges and the time of observation not being sufficiently precise to be of value for the discussion in hand.

The stations are arranged from south to north in their respective counties, and the counties are arranged in the order adopted by the Registrars-General. This order is the same as that used in *British Rainfall*, and will therefore probably be that most familiar to rainfall observers.

The 521 stations are for all the calculations of the paper reduced to 515, six (marked with an *) being omitted, as they evidently include rain which properly belongs to January, but which was entered to the wrong day. Of these stations 385 are in England, 32 in Wales, 52 in Scotland, and 46 in Ireland.

Assuming that the average of these stations fairly represents the mean fall over the different countries, we have for England an average total for the month of only 0·130 in., but if we exclude the Lake District, *i.e.* Cumberland, Westmoreland, and North Lancashire, where the fall at several stations exceeded an inch, we have a fall over the remainder of the country of only 0·066 in., or about one fortieth of the average.

At 284 stations, or 74 per cent of the whole number, the rainfall did not exceed 0·10 in., while at 50, or 13 per cent. of the stations, no rain was recorded.

As regards the distribution over the different counties, the data available are set out in Table I. They are however insufficient to give complete information, as several counties are represented by only one station, and some are not represented at all.

Those for which we have sufficient data are :—

[1] Not printed herewith.

County.	Mean Rainfall.	County.	Mean Rainfall.
	In.		In.
Middlesex	·004	Suffolk	·059
Cambridge	·029	Kent	·065
Hertford	·030	Northampton	·071
Gloucester	·033	Hampshire	·075
Surrey	·036	York	·100
Sussex	·042	Cornwall	·162
Norfolk	·053		
Devon	·058	Lancashire	·488

The only counties with a mean rainfall of more than ·10 in. are:

County.	Mean Rainfall.	County.	Mean Rainfall.
	In.		In.
*Shropshire	·105	*Cheshire	·182
*Leicester	·110	*Derby	·280
*Lincoln	·144	Lancashire	·488
Cornwall	·162	Cumberland	·726
*Warwick	·170	Westmoreland	1·001

The mean for Derby is greatly raised by a large fall in the Peak district, and for Lancashire, by that in the hill district in the north, the mean for the southern half of the county being only ·166 in.

The counties from which no reports exceeding ·10 in. have been received are Middlesex, Surrey, Hertford, Buckingham, Oxford, Huntingdon, Bedford, Cambridge, Wilts, Dorset, Somerset, Hereford, Worcester, and Rutland, while those from which no station reports so small a fall as ·10 in. are Warwick, Cheshire, Cumberland, and Westmoreland.

By grouping the counties into the divisions adopted by the Registrar-General, we get a sufficient number of stations in each to give very reliable means, which are given in Table I. and summarised in Table II.

In this method of comparison Middlesex, as Division I, again carries off the palm with its mean rainfall of ·004 in., all its stations reporting less than ·10 in., and 57 per cent. of them ·00 in. Division III., South Midland Counties, comes next with a mean rainfall of ·038 in., 95 per cent. of its stations not exceeding ·10 in., and 22 per cent. reporting ·00 in. These two are the only divisions with a mean rainfall of less than ·05 in. Then follows Division IV., Eastern Counties, mean rainfall ·054 in.; 87 per cent. of the stations not exceeding ·10 in., and 11 per cent. reporting ·00 in.; Division VI., West Midland Counties, mean rainfall ·057 in., 83 per cent. of the stations not exceeding ·10 in., and 10 per cent. of ·00 in.; Division II., South Eastern Counties, mean rainfall ·058 in., 85 per cent. of the stations not exceeding ·10 in., and 17 per cent. with ·00 in.; Division V., South Western Counties, mean rainfall ·072 in., 79 per cent. of the stations not exceeding ·10 in., and

* For these counties the number of returns is too small to give a thoroughly reliable mean.

TABLE I.

MEAN RAINFALL OF THE COUNTIES AND DIVISIONS, FEBRUARY 1891.

County and Division.	No. of Stations.	Mean Rainfall.	No. of Records not exceeding 0·10 in.	No. of Records of 0·00 inch.	County and Division.	No. of Stations.	Mean Rainfall.	No. of Records not exceeding 0·10 in.	No. of Records of 0·00 inch.
I.		In.			X.		In.		
Middlesex	7	·004	7	4	Durham	5	·056	4	0
Division	7	·004	7	4	Northumberland	9	·094	6	0
II.					Cumberland	16	·726	0	0
Surrey	9	·036	9	2	Westmoreland	9	1·001	0	0
Kent	17	·065	15	2	Division	39	·558	10	0
Sussex	9	·042	9	3	XI.				
Hants	13	·075	8	1	Monmouth	3	·033	3	1
Division	48	·058	41	8	Glamorgan	2	·095	1	0
III.					Carmarthen	2	·250	0	0
Herts	25	·030	25	5	Pembroke	3	·143	1	0
Bucks	1	·000	1	1	Cardigan	3	·230	1	0
Oxford	4	·013	4	2	Brecknock	2	·180	1	0
Northampton	21	·071	17	0	Radnor	3	·150	1	0
Hunts	1	·000	1	1	Montgomery	3	·250	1	0
Bedford	5	·004	5	4	Merioneth	2	·345	1	1
Cambridge	19	·029	19	4	Carnarvon	3	·190	1	0
Division	76	·038	72	17	Anglesea	1	·280	0	0
IV.					Isle of Man	1	·240	0	0
Essex	7	·049	6	1	Scilly	1	·020	1	0
Suffolk	8	·059	6	1	Jersey	2	·055	2	0
Norfolk	40	·053	36	4	Guernsey	1	·060	1	0
Division	55	·054	48	6	Division	32	·170	15	2
V.					XII.				
Wilts	5	·014	5	1	Southern Counties	5	·344	1	0
Dorset	6	·013	6	3	XIII.				
Devon	28	·058	24	3	S.E. Counties	4	·478	0	0
Cornwall	14	·162	6	0	XIV.				
Somerset	4	·018	4	1	S.W. Counties	4	·475	0	0
Division	57	·072	45	8	XV.				
VI.					W. Mid. Counties	8	2·824	0	0
Gloucester	23	·033	22	4	XVI.				
Hereford	3	·037	3	0	E. Mid. Counties	7	·831	0	0
Shropshire	2	·105	1	0	XVII.				
Stafford	4	·098	2	0	N.E. Counties	6	·897	0	0
Worcester	6	·058	6	0	XVIII.				
Warwick	3	·170	0	0	N.W. Counties	10	3·294	0	0
Division	41	·057	34	4	XIX.				
VII.					Northern Counties	8	2·468	0	0
Leicester	3	·110	1	0	XX.				
Rutland	2	·070	2	0	Cork	4	·648	0	0
Lincoln	5	·144	1	0	Kerry	4	·745	0	0
Notts	3	·093	2	0	Waterford	1	·330	0	0
Derby	5	·230	1	0	Tipperary	2	·350	0	0
Division	18	·146	7	0	Limerick	1	·180	0	0
VIII.					Clare	4	·367	0	0
Cheshire	4	·182	0	0	Division	16	·516	0	0
(S. Lancashire)	(8)	(·166)	(3)	(0)	XXI.				
Lancashire	15	·488	3	0	Wexford	1	·240	0	0
Division	19	·424	3	0	Carlow	1	·280	0	0
IX.					King's County	1	·180	0	0
Yorkshire	25	·100	17	3	Dublin	1	·040	1	0
Division	25	·100	17	3	Westmeath	2	·270	0	0

TABLE I.

MEAN RAINFALL OF THE COUNTIES AND DIVISIONS, FEBRUARY 1891.—*Continued.*

County and Division.	No. of Stations.	Mean Rainfall.	No. of Records not exceeding 0·10 in.	No. of Records of 0·00 inch.	County and Division.	No. of Stations.	Mean Rainfall.	No. of Records not exceeding 0·10 in.	No. of Records of 0·00 inch.
		In.			XXIII.		In.		
Longford	1	·220	0	0	Cavan	1	·260	0	0
Division	7	·214	1	0	Down	4	·222	0	0
XXII.					Antrim	3	·307	0	0
Galway	4	·473	0	0	Londonderry	1	·250	0	0
Mayo	2	·710	0	0	Tyrone	2	·550	0	0
Sligo	2	·380	0	0	Donegal	3	·413	0	0
Leitrim	1	·550	0	0	Division	14	·388	0	0
Division	9	·513	0	0					

14 per cent. with ·00 in. The remaining Divisions all had a mean rainfall exceeding ·10 in.

The Welsh returns are set out like the English ones in counties, but owing to the paucity of stations and the very varied physiography of the country, it is useless to deal with the counties individually. The 32 stations give a mean fall of ·170 in., 15 stations or 47 per cent. report falls not exceeding ·10 in., while 2 or 6 per cent. report no rain. It is difficult to form any idea of the mean rainfall over such a country as Wales, but probably this ·170 in. is not more than one twentieth of the average for the month.

In Scotland, as in Wales, the physical features vary greatly even in a single county, and the rainfall there though small was not phenomenally so. I have therefore in Table I. given only the totals for each division. For the present purpose the country may be divided into two fairly equal parts, the east and south, where there was a great deficiency: and the west and north, where the fall was normal.

The east and south comprises Divisions XII., Southern Counties; XIII., South Eastern Counties; XIV., South Western Counties; XVI., East Midland Counties; and XVII., North Eastern Counties. Reports have been received from 26 stations, and give a mean rainfall of ·644 in.: only one station reports less than ·10 in., and not one ·00 in. The mean though small is not unprecedented and is probably about one fifth of the average for the month.

The west and north comprises Division XV., West Midland Counties; Division XVIII., North Western Counties; and Division XIX., Northern Counties. The number of returns is 26, the mean rainfall 2·895 ins., and no station reports less than ·10 in., in fact only one station had less than an inch, while the largest record is 8·78 ins. This part of the Kingdom probably had about three fourths of the average.

Taking Scotland as a whole, the 52 stations give the very respectable mean fall of 1·769 in.

TABLE II.

MEAN RAINFALL AND NUMBER OF STATIONS AT WHICH THE FALL DID NOT EXCEED 0·10 IN., AND AT WHICH NO RAIN WAS RECORDED DURING FEBRUARY 1891.

Division.	Number of Stations.	Mean Rainfall.	Stations with Rainfall not above ·10 in.		Stations with no rain.	
			Number.	Per cent. of Total Number.	Number.	Per cent of Total Number.
ENGLAND.		In.				
I. Middlesex	7	·004	7	100	4	57
II. South Eastern Counties	48	·058	41	85	8	17
III. South Midland „	76	·038	72	95	17	22
IV. Eastern „	55	·054	48	87	6	11
V. South Western „	57	·072	45	79	8	14
VI. West Midland „	41	·057	34	83	4	10
VII. North „ „	18	·146	7	39	0	0
VIII. „ Western „	19	·424	3	16	0	0
VIII. Exclusive of N. Lancashire	(12)	(·172)	(3)	(25)	(0)	(0)
IX. Yorkshire	25	.100	17	68	3	12
X. Northern Counties..	39	·558	10	26	0	0
X. Exclusive of Cumberland and Westmoreland....	(14)	(·081)	(10)	(71)	(0)	(0)
England	385	.130	284	74	50	13
„ exclusive of the Lake District	353	·066	284	80	50	14
XI. Wales, Monmouth, &c.	32	·170	15	47	2	6
SCOTLAND.						
XII. Southern Counties	5	·344	1	20	0	0
XIII. South Eastern „	4	·478	0	0	0	0
XIV. „ Western „	4	·475	0	0	0	0
XV. West Midland „	8	2·824	0	0	0	0
XVI. East „ „	7	·831	0	0	0	0
XVII. North Eastern „	6	·897	0	0	0	0
XVIII. „ Western „	10	3·294	0	0	0	0
XIX. Northern „	8	2·468	0	0	0	0
Scotland	52	1·769	1	2	0	0
„ E. & S. half......	26	·644	1	4	0	0
„ W. & N. „	26	2·895	0	0	0	0
IRELAND.						
XX. Munster	16	·516	0	0	0	0
XXI. Leinster	7	·214	1	14	0	0
XXII. Cannaught	9	·513	0	0	0	0
XXIII. Ulster	14	·388	0	0	0	0
Ireland	46	·414	1	2	0	0
„ Western half......	25	·514	0	0	0	0
„ Eastern „	21	·293	1	5	0	0

Adhering to the Divisions of the Registrar-General, Ireland, like Scotland, may be conveniently divided into halves—Munster and Connaught in the west; and Leinster and Ulster in the east: the western half being naturally the wetter.

From Munster and Connaught, 25 stations give a mean rainfall of half-an-inch (·514 in.), and no record so small as ·10 in.

From Leinster and Ulster, 21 stations give a mean rainfall of ·298 in., and one station (Dublin) reports less than ·10 in. (·04 in.).

These two mean falls of ·514 in. and ·298 in. bear very nearly the same relation to the average of the two portions of the Kingdom in which they

occur. The mean for the whole country based on the 46 stations is ·414 in., which is about an eighth of the average for the month.

A better idea of the fall over Ireland may be obtained by ignoring the boundaries of the provinces, and even to a certain extent the boundaries of the counties, when we find, as might be expected, that the fall increases steadily from east to west. The returns from the counties on the east coast give a mean of ·20 in., those from the centre and north of the country a mean of ·85 in., while the mean for the west and south-west is ·60 in.

In Table III. I have given the rainfall returns for 20 continental stations, distributed over the west of Europe from the Mediterranean to Sweden; at only 8, (Nice, ·95 in.; Munich, ·56 in.; and Stockholm, ·51 in.) did the fall exceed half-an-inch, while at 6 it was less than ·10 in.

	In.			
Lorient	·00	on	0	days
Lyons	·04	,,	1	,,
Belfort	·04	,,	1	,,
Brest	·04	,,	1	,,
Wiesbaden	·04	,,	1	,,
Rochefort	·08	,,	2	,,

M. A. Lancaster states in *Ciel et Terre*[1] that in the month of February the mean total rainfall for the whole of Belgium was only ·16 in.

TABLE III.

RAINFALL AT CONTINENTAL STATIONS IN FEBRUARY 1891.

Station.	Rain.	No. of days.	Station.	Rain.	No. of days.
	In.			In.	
Biarritz	·12	2	Wiesbaden	·04	1
Perpignan	·24	2	Brussels	·16	5
Nice	·95	1	Cape Gris Nez	·16	3
Lyons	·04	1	Berlin	·32	4
Rochefort	·08	2	The Helder	·28	3
Belfort	·04	1	Cuxhaven	·40	4
Lorient	·00	0	Copenhagen	·47	3
Brest	·04	1	The Skaw	·35	3
Munich	·56	6	Stockholm	·51	3
Paris	·12	2	Christiania	·39	5

Precise comparison of February 1891 with previous exceptionally dry months is difficult, owing to the fact that before the foundation of the Rainfall Organisation in 1860 the same precision was not observed with regard to small falls of rain, or to the measurement of snow. The number of stations also was very limited.

Table IV. contains all records of months with a total rainfall not exceeding a quarter of an inch at 12 stations fairly distributed over the British Isles, whose records extend over an aggregate period of 728 years, or an average of 61 years. The records are not all absolutely continuous, but I have used

[1] Vol. XII. p. 45.

much care in selecting them, and the two stations at Cork are the only case in which there was any material difference in the position of the two gauges. Every entry in the table has been compared with, and is thoroughly substantiated by, the records of neighbouring gauges.

This table indicates that, speaking of the British Isles as a whole, a month with not more than a quarter of an inch of rain will occur once in 9 years. But when we examine the stations individually we come upon, what is to me, a new phenomenon in rainfall statistics. The frequency of the occurrence of such a dry month varies from once in 3·6 years at Boston to once in 60 years at Orleton. This variation is enormous, and at once suggests inaccuracy, but I can find no error. The 3·6 at Boston is supported by 4·5 at Exeter and 5·7 at Cork. The Exeter Institution record, extending over 74 years, gives 1 in 8·9, and the record at Spalding, Pode Hole, extending over 62 years, agrees very closely with that at Boston. The Orleton value of 1 in 60 years is supported by Haverfordwest with no record in 42 years, but Haverfordwest has a mean annual rainfall of nearly 50 ins., while Orleton has a mean of about 30 ins., practically the same as Exeter.

Accepting the results given by the table, and examining them with respect to monthly frequency, we find that they group themselves in the following order:—

May with a rainfall not exceeding	·25 in.,	once	in	34·7	years
April	,,	,,	,,	,,	52·0	,,
June	,,	,,	,,	,,	60·0	,,
February	,,	,,	,,	,,	104·0	,,
March and December	,,	,,	,,	,,	121·3	,,
September	,,	,,	,,	,,	145·6	,,
January	,,	,,	,,	,,	242·7	,,
July, August, and October		,,	,,	,,	364·0	,,
November		,,	,,	,,	728·0	,,

The place which February takes in the table is in a great measure due to its shortness, and in the month under discussion, February 1891, the result would be very different if we added one day at each end, for at many stations rain was recorded both on January 31st and on March 1st.

Two of the driest months in recent times in England and Wales were September 1865 and June 1887, but neither of these bear comparison with February 1891.

In September 1865, out of a total of 770 stations, 129, or 17 per cent., recorded less than ·10 in.; and 48, or 6 per cent., no rain.

In June 1887—101 stations, at 9, or 9 per cent., the fall did not exceed ·10 in., and at 2, or 2 per cent., no rain was recorded.

In February 1891—385 stations, at 284, or 74 per cent., the fall did not exceed ·10 in., and at 50, or 13 per cent., no rain was recorded.

On page 157 of *British Rainfall* 1887, I find with reference to June of that year:—" In the South Western Counties, with an average annual rainfall varying from 30 ins, to about 100 ins., the deficiency was exceptionally great,

TABLE IV.

Table of Monthly Rainfalls not exceeding 0·25 in.

Stations.	January. In.	January.	February. In.	February.	March. In.	March.	April. In.	April.	May. In.	May.
Chichester, Chilgrove	..	..	..	..	·00	1840	·16	1854	·21	1880
	..	..	..	..	..	..	·21	1870	..	..
Exeter, St. Thomas's and Manston Terrace	·00	1855	·19	1887	·06	1840	·00	1817	·10	1814
	..	..	..	..	..	..	·22	1854	·10	1844
	..	..	..	..	..	..	·20	1861	·24	1871
	..	..	..	..	..	..	·15	1870	..	..
Tenbury, Orleton	..	..	..	..	..	..	..	..	..	..
Boston and Grand Sluice	·12	1826	·12	1832	·17	1829	·20	1852	·22	1829
	·21	1880	·22	1849	·12	1830	·23	1855	·18	1848
	..	..	·25	1858	·25	1856	..	..	..	..
Bolton, The Folds	..	..	·05	1858	..	..	·00	1842	·18	1836
	..	..	..	..	..	..	..	..	·20	1844
York, Bootham and Phil. Soc.	..	..	·16	1832	..	..	·18	1855	·21	1836
	..	..	..	..	..	..	·24	1861	..	..
Haverfordwest	..	..	..	..	..	..	..	..	..	..
Pentland Hills, Glencorse	..	..	..	..	·10	1856	·00	1842	·10	1859
Cork, Royal Institution and Blackrock	..	..	..	..	..	..	·05	1854	·07	1836
	..	..	(·22[1])	1877	..	..	..	..	·10	1839
	..	..	(·27[2])	1888	..	..	..	..	·14	1844
	..	..	..	..	..	..	..	..	·02	1861
	..	..	..	..	..	..	..	..	·15	1874
	..	..	..	..	..	..	..	..	·10	1876
Dublin, Phœnix Park	..	..	..	..	..	..	..	..	..	..
Collooney, Markree Obs. and Sligo, Mount Shannon	..	..	..	..	..	..	..	..	·24	1836
	..	..	..	..	..	..	..	..	·14	1844
Belfast, Linen Hall, and Queen's College	..	..	..	..	..	..	·17	1842	·23	1824
	..	..	..	..	..	..	..	..	·25	1836
	..	..	..	..	..	..	..	..	·19	1859
Total	..	3	..	7	..	6	..	14	..	21
Frequency 1 in	..	242·7	..	104·0	..	121·3	..	52·0	..	34·7

Stations.	June. In.	June.	July. In.	July.	August. In.	August.	September. In.	September.	October. In.	October.
Chichester, Chilgrove	..	..	..	..	..	..	·00	1851	..	..
Exeter, St. Thomas's and Manston Terrace	·13	1870	·00	1825	·07	1818	·03	1865	..	..
	·06	1887	..	..	..	..	..	..	..	..
	·21	1889	..	..	..	..	..	..	..	..
Tenbury, Orleton	..	..	..	..	..	..	·11	1865	..	..
Boston and Grand Sluice	·21	1826	..	..	·15	1861	..	..	..	..
	·16	1887	..	..	..	..	..	..	..	..
Bolton, The Folds	..	..	..	..	..	..	..	..	..	..
York, Bootham and Phil. Soc.	·16	1887	..	..	..	..	·23	1865	·20	1834
Haverfordwest	..	..	..	..	..	..	..	..	..	..
Pentland Hills, Glencorse	..	..	..	..	..	..	..	..	..	..
Cork, Royal Institution and Blackrock	·13	1826	..	..	..	..	..	..	·24	1840
	·06	1869	..	..	..	..	..	..	..	..
Dublin, Phœnix Park	·15	1887	..	..	..	..	·10	1865	..	..
	·10	1889	..	..	..	..	..	..	..	..
Collooney, Markree Obs. and Sligo, Mount Shannon	·14	1887	·23	1863	..	..	..	..	..	..
Belfast, Linen Hall and Queen's College	·07	1821	..	..	..	..	..	..	..	..
Total	..	12	..	2	..	2	..	5	..	2
Frequency 1 in	..	60·7	..	364·0	..	364·0	..	145·6	..	364·0

[1] Incorrect, not included.

TABLE IV.

TABLE OF MONTHLY RAINFALLS NOT EXCEEDING 0·25 IN.—*Continued.*

Stations.	November.		December.		No. of Years' Record.	No of instances.	Frequency.
	In.		In.				Years.
Chichester, Chilgrove	..	..	..	..	57	5	11·4
Exeter, St. Thomas's and Manston Terrace	·12	1879	..	..	77	17	4·5
Tenbury, Orleton	..	..	..	..	60	1	60·0
Boston and Grand Sluice	..	..	·20	1829	65	18	3·6
	..	..	·27	1835	..	..	..
	..	..	·12	1843	.	..	..
Bolton, The Folds	..	..	·22	1844	60	5	12·0
York, Bootham and Phil. Soc.	..	..	·22	1843	60	8	7·5
Haverfordwest	..	.	..	..	42	0	..
Pentland Hills, Glencorse	..	..	·20	1844	61	4	15·3
Cork, Royal Institution and	..	..	..	..	63	11	5·7
Blackrock	..	..	..	..	..	..	..
Dublin, Phœnix Park	..	..	..	..	54	3	18·0
Collooney, Markree Obs. and Sligo, Mount Shannon	..	..	..	..	58	4	14·5
Belfast, Linen Hall & Queen's College	..	..	..	..	71	5	14·2
Total	..	1	..	6	728	81	9·0
Frequency 1 in	..	728·0	..	121·3	..	..	..

and probably the following list of stations, which report no measureable quantity of rain in the whole of the calendar month, is one of the most remarkable tables in the annals of rainfall work:"—

County.	Station.
Devon	Starcross, Powderham Castle.
,,	Rousdon Observatory (monthly gauge).
,,	Exeter Institution.
,,	Hatherleigh, Winsford.
Cornwall	Probus Lamellyn.
,,	Par Station, Penellick.
,,	Liskeard, St. Cleer.
,,	Bude.

It is rather curious that this table contains exactly the same number of stations in the South Western Counties reporting no rain, as I have in my present tables, but no doubt when the whole 8,000 returns for 1891 are worked up the 8 will be increased to 16 or more.

The effect of such a month as February on the water supply of the country is difficult to realise, the deficiency may be roughly taken at

250 tons per acre over the whole of England.
300 ,, ,, ,, ,, ,, Wales.
150 ,, ,, ,, ,, ,, Scotland.
800 ,, ,, ,, ,, ,, Ireland.

I have said nothing about the number of rainy days. I feel that in the present case they are more an indication of personal equation than of anything else. A zealous observer finds in his gauge a quantity of about ·005 in., he resists the temptation to throw it away, and with the spirit of a martyr enters a fall of rain and a rainy day. Another, equally zealous and conscientious, gives the month the benefit of the doubt, and produces triumphantly a blank record. Even at the headquarters of British Rainfall the only entry during the month, ·01 in. on the 7th, was suspended till the reading of the weekly gauge should decide whether it was to be entered or not.

"SOUTH-EAST FROSTS,"

WITH SPECIAL REFERENCE TO THE FROST OF 1890-91.

BY REV. FENWICK W. STOW, M.A., F.R.Met.Soc.

[Read April 15th, 1891.]

THIRTY years ago and more, when I first began to take Meteorological Observations in Yorkshire, I noticed that while frost usually came with North and North-east winds, it sometimes came with South-east winds. In the latter case I found that there was little fear of the skating being spoilt by snow; the frost was sure to be sharp while it lasted, but it was not likely to last long.

The first of these South-east frosts which I noticed, and of which I kept a register, was in December 1855. The frost of last winter, which was also a South-east frost till the end of December, seemed therefore quite like an old friend to me.

I have extracted from my register some particulars about all the frosts, beginning with 1855, which I believe to have been of this character.

I may be mistaken about some of them. It often happens that what is evident at the time to an observer is not so evident when studied in a record. I have, however, a clear recollection of most of these frosts, and I trust that my list is fairly correct. I am somewhat doubtful about the frosts of 1870, for reasons which I give in a note.[1]

[1] In 1870 I was at Hawsker, near Whitby. On the sea coast meteorological conditions are subject to much local variation. Great precipitation often occurs on the coast when fine and dry weather is prevalent inland. Moreover, the direction of the wind at a coast station is locally affected both by the character of the coast, which often makes it easier for the wind to blow *along* it rather than across it, and also by the differences of temperature between sea and land, which tend to make the wind blow from whichever is the colder.

LIST OF "SOUTH-EAST FROSTS" OBSERVED IN YORKSHIRE.

Place.	Year.	Date of commencement of Frost.	Duration. Days.	Temperature. Lowest Min.	Temperature. Date.	Temperature. Lowest Max.	Temperature. Date.	General Direction of Wind.
				°		°		
Red Hall, near Leeds	1855	Dec. 18	6	18·0	21st	24·0	21st	SE
"	1858	Jan. 1	8	23·3	5th	29·5	6th	ESE
"	1861	Dec. 24	8	23·0	30th	34·0	29th	ESE & SSE
"	1862	Jan. 15	10	19·0	19th	29·5	21st	SE & ESE
Harrogate	1863	Dec. 31	11	13·5	8th	23·5	7th	SE
Ripon..........	1864	Dec. 23	8	19·2	27th	26·5	25th	SE, E, & SSE
Hawsker, near Whitby	1870	Feb. 8[1]	8	13·4	12th	29·8	12th	ESE & SE
"	1870	Dec. 21	45	9·0	31st Dec.	25·0	Jan. 1st	E, and then chiefly S
Aysgarth	1880	Jan. 8	23	17·0	19th	28·5	13th	E and SE, then calm and variable
"	1887	Jan. 14	6	17·0	17th	29·8	16th	SE & SSE
"	1889	Dec. 27	5	21·8	29th	30·0	28th	ESE & SE
"	1890	Dec. 7	47	12·5 7·9	Dec. 14th Jan. 18th	25·8	13th Dec.	SE

1 Perhaps a doubtful case.

REMARKS.—Red Hall: 1855, weather generally bright, thawed with South-west wind; 1858, began calm, with hoar frost; 1861, thawed with North wind. Harrogate: 1863, weather generally bright. Hawsker: 1870, much wind and snow on coast, thawed with North-east wind, frost severe on Continent. Aysgarth: 1880, frost most intense when wind East and South-east; 1887, thawed with South-west wind; 1889, ditto.

Looking at the list, then, it seems worthy of remark that the only "South-east Frosts" which lasted more than about 10 days occurred at intervals of about 10 years, namely in 1870-1, in January 1880, and in 1890-1. These lasted 45, 23 and 47 days respectively. They were coincident in time with frost of extreme severity in France and central Europe. As might be expected, there was keener frost in the south-east of England than in the north, and comparatively mild weather prevailed, I believe, in Scotland and in Norway.

But the great frosts of January and February 1855, 1860-1, December 1874, 1878-9, and January 1881 were not "South-east Frosts." I cannot compare the intensity of the two first with last winter's frost, not having observed them in the same locality. But for duration of cold 1878-9 carries off the palm, since the mean temperature of the three months, December, January and February, was as low as 30°·4. For severity nothing approaches to January 1881, when the mean of 21 consecutive days was 21°·6 at Aysgarth, and at stations in the valleys considerably below 20°. Last winter the mean of December was 31°·1, and of January 33°·9.

"South-east Frosts" are more easily distinguished from others in the north of England than in the south, both by the direction of the wind and by absence of snowfall.

In the south-east of England the wind is generally East and not South-east, and sometimes even North-east. In Yorkshire it is generally between East-south-east and South-south-east. In Scotland and Ireland it may blow from South-south-east, South, or South-south-west, but only a native of the "Emerald Isle" could speak of a South-east Frost there, seeing that in such cases they have usually no frost at all. Probably an anticyclone over north Germany or the south of Norway usually occurs when a South-east Frost occurs in Yorkshire, which might account for the curl of the wind on its way north.

Returning, then, to the north of England, I would say that the distinguishing points in "South-east Frosts" are these:—

1. A wind from some quarter between East and South-south-west, but usually between East-south-east and South-south-east.

2. Absence of snow so long as the wind holds in the South-east. This hardly applies to the south of England, where the wind has just crossed the Channel and contracted some moisture. In Yorkshire a fall may occur if a temporary shift of the wind to North-east happens without bringing on a thaw.

3. A small range of temperature with especially low maxima.

4. Rarely a cloudless sky, more generally one that is dull, dry and dirty-looking, the sun having little power, and terrestrial radiation being also weak.

5. If the frost continues the wind generally falls light and fog prevails in the lowlands.

6. A decided shift of the wind to any other quarter brings a tendency to thaw, and especially if it becomes North or North-west.

It seems probable that any very severe frost on the Continent tends to produce a "South-east Frost," provided that there is milder weather over our Islands at the time, and the difference of temperature is therefore large.

It cannot be denied that the surface wind has an unpleasant tendency to blow from wherever the temperature is lowest, to whatever extent this tendency may be over-balanced by the great general movements of the atmosphere, which, however, themselves are of necessity set in motion on a vast scale by the same tendency, which *e.g.* produces the Trade Winds.

Given, therefore, a severe frost on the Continent, a milder temperature over our Islands and an approximate state of equilibrium to the westward of them (the greater movements of the atmosphere thus offering no hindrance), it may be expected that a South-east wind will rise and bring the cold to us. But, of course, it very often happens that some eddy of the great South-west Atlantic wind interferes with the "South-east Frost" within a very few days, or prevents it from coming on at all.

Towards the end of a long frost of any kind, there are often bitter winds from East and South-east, when the frost on the Continent has become very severe. No doubt the conditions are then somewhat similar to those which I have described in the case of "South-east Frosts." But the sky is then as a rule entirely overcast, and it is probable that a "depression" has appeared in the west, and that a change will soon occur.

In considering the frost of last winter as a "South-east Frost," I must explain that I mean the frost which began December 7th, 1890. There was frost (with snow) from November 24th to 30th. That came from the north-east. Intense cold was reported in Lapland, which speedily pushed its way south-westwards. A milder temperature in the north quickly followed in the wake of this cold wave. But in France and Central Europe the wave was arrested and the cold continued. And by December 7th the conditions were favourable for a "South-east Frost" of the kind which I have described. No snow fell here at first, and very little before Christmas. There were few clear nights or days. With its cold, dull, dry and dreary weather, and steady penetrating frost day and night, last December was a joy to skaters but not to everybody.

The brilliant, cloudless, sunny days, which are so pleasant a feature of frosty weather in the Yorkshire dales, were few. Scarcely 29 hours of bright sunshine were registered in the month, of which 24 occurred on 5 days only. A photographic incident will illustrate the dulness of the weather. I exposed a plate at noon in the same spot and on practically the same view which I had taken some years ago during a bright February frost in *6 seconds*. This time I gave *12 minutes* with the same stop, and the plate was rather under-exposed. There was no snow on the ground on either occasion, nor was there any fog or other non-actinic condition on the latter day. The plate used in December 1890 was about twice as slow, but even allowing for this, the difference is enormous. Sometimes the cloud canopy was very low. On one day, at all events, we were above it.

A peculiarity of the late frost was that an increase of cold occurred in January 1891 with a North wind, and the conditions were then altered. It became much colder in the north, and the sky brightened, and after a fall of snow the frost culminated in very low temperatures on the 18th. In more than one low-lying place near Bedale $-8°$ was observed. But the "South-east Frost" was really over early in January, and had been succeeded by one of ordinary type.

RAIN GAUGES, EVAPORATION GAUGES, ETC.

Twelfth Annual Exhibition of Instruments,

Held, by permission of the Council of the Institution of Civil Engineers, at 25 Great George Street, Westminster, S.W.

MARCH 3RD TO 19TH, 1891.

OLD PATTERN RAIN GAUGES.

12-INCH GAUGES.

1. **Side Tube Rain Gauge**. The water passes into the body of the gauge, and also into the glass tube, and stands at the same level in each. As the combined area of these tubes is very much less than that of the receiving surface, the natural depth of the rain is proportionally increased, and thus the scale is lengthened in proportion—usually about eight or ten times,—so that the quantity can be read off to hundredths of an inch. *Exhibited by* Messrs. NEGRETTI AND ZAMBRA.

2. **Contracted Float Gauge**. In this pattern, instead of having a glass tube, which is very liable to breakage, the receiver contains a copper float, to the upper side of which a rod is attached. When rain falls the rod is lifted, and owing to the small area of the body of the gauge as compared with that of the rim, the float rises about eight times the natural depth of the rain—this cannot easily be read nearer than to $\frac{1}{50}$th of an inch. *Exhibited by* Messrs. NEGRETTI AND ZAMBRA.

10-INCH GAUGES.

3. **Old Copper Rain Gauge**, constructed in 1855 and used at the Kew Observatory till June 1890; square funnel, receiving area 100 sq. ins. *Exhibited by the* KEW COMMITTEE.

8-INCH GAUGES.

4. **Glaisher's earliest cylindrical form**, with bevelled rim and curved pipe. The rim round the gauge, about $\frac{2}{3}$ of the way up, was designed to make a water-tight joint, so as to prevent any of the rain inside escaping by evaporation. The same object was aimed at by the curved tube or inverted siphon, in which the last few drops of rain remained and (until they dried up) formed a water-seal. *Exhibited by* Messrs. NEGRETTI AND ZAMBRA.

5. **FitzRoy's Rain Gauge**. This is cylindrical in shape with a funnel let into the top; and the rainfall is collected in an inner and much smaller cylinder. The amount of rain is ascertained by a graduated dipping tube which has a hole at each end. This tube is placed upright in the gauge with its upper end open, then the thumb is pressed on the upper aperture while the tube is lifted gently out, holding in the lower part a quantity of water representing the depth of rain in the gauge. The graduations on the tube are fixed by actual trial with an ordinary rain gauge. *Exhibited by* THE METEOROLOGICAL COUNCIL.

5-INCH (AND SMALLER) GAUGES.

6. **Howard's Rain Gauge.** Designed by Luke Howard, F.R.S., and engraved in the first edition of his *Climate of London*, published in 1818. The area of the funnel is about eleven times that of the measuring jar, so that minute measurements are possible.
Exhibited by Messrs. NEGRETTI AND ZAMBRA.

7. **Howard's Rain Gauge** with stoneware bottle instead of glass, introduced about 1850 with the view of reducing the frequency of breakage.
Exhibited by L. P. CASELLA, F.R.Met.Soc.

8. **Howard's Rain Gauge** as modified by the late Mr. H. H. Treby of Goodamoor, rough divisions being put upon the bottle so that an approximate idea of the amount of fall might be obtained without the gauge being interfered with. *Exhibited by* L. P. CASELLA, F.R.Met.Soc.

9. **Howard's Rain Gauge,** a first modification by Mr. G. J. Symons, being an attempt to protect the glass bottle, and yet allow of inspection as in Mr. Treby's gauge. This gauge, however, had two faults, the bottle did not hold enough, and if it burst, the can being pierced could not save the water. *Exhibited by* Messrs. NEGRETTI AND ZAMBRA.

10. **Symons's Rain Gauge.** This was the previous gauge so modified as to remove the above mentioned evils, the bottle was larger and the can watertight.
Exhibited by L. P. CASELLA, F.R.Met.Soc.

11. **5-in. Side Tube Rain Gauge.** *Exhibited by* L. P. CASELLA, F.R.Met.Soc.

12. **Coffee-Pot Rain Gauge**—so called from its shape. This was a very handy gauge, but it had two faults: (1) that it was frequently blown over—this could be cured by suitable hooks; (2) it was the worst possible pattern for frost—this latter fault was incurable.
Exhibited by G. J. SYMONS, F.R.S.

13. **Stevenson's Rain Gauge.** This was an attempt to bring the rim of the gauge to the level of the ground, and yet to avoid insplashing. The inventor advised having a brush made to surround the gauge, but as tried at Strathfield Turgiss a small mat with a hole in it was substituted. Mr. Griffith reported that it was a very difficult gauge to work, and that its chief efficiency was in collecting insects.
Exhibited by G. J. SYMONS, F.R.S.

14. **Fleming's Rain Gauge.** This is a very small float gauge, formerly much used in Scotland, but now nearly abandoned, because when the quantity of rain collected exceeds 2 inches, rain which ought to pass over the gauge is caught by the measuring rod and runs down it into the gauge. It was also usually placed so nearly level with the ground that surface water occasionally entered, and it had other faults.
Exhibited by G. J. SYMONS, F.R.S.

EXPERIMENTAL RAIN GAUGES.

15. From Col. Ward's original magnitude series—the 2 in., 4 in., and 12 in. circular gauges, and the 5 in. and 10 in. square ones. (This last is what used to be known as the Royal Engineer's Rain Gauge.)

16. From Col. Ward's original elevation series—the gauges were all identical—the 10 ft. one only is exhibited.

17. From the series constructed for Mr. Symons to test the effect of various receiving surfaces (tin, copper, glass, porcelain and ebonite), the porcelain one, worked successively at Camden Square, at Framfield, Sussex, and at Strathfield Turgiss is exhibited.
Exhibited by G. J. SYMONS, F.R.S.

NEW PATTERN RAIN GAUGES.

8½-INCH GAUGE.

18. **Rain Gauge 8½ inches in diameter** employed by the Manchester, Sheffield, and Lincolnshire Railway Co. *Exhibited by* THE M. S. & L. R. Co.

8-INCH GAUGES.

19. **Meteorological Office Gauge.** This is generally regarded as the best gauge for ordinary observers to whom cost is not a primary object. It has all the good features of the Glaisher and of the Snowdon patterns, and being of copper is of course very durable.
Exhibited by THE METEOROLOGICAL COUNCIL.

20. **Glaisher's Gauge.** This is the Glaisher pattern, modified by the substitution of a vertical rim (to cut the rain drops) for the original bevelled one on which they would break, and by the substitution of a long straight pipe for the curved one which was found to be frequently choked with leaves, &c. *Exhibited by* Messrs. NEGRETTI AND ZAMBRA.

5-INCH GAUGES.

21. **Symons's Snowdon Gauge.** In the autumn of 1864 the late Major Mathew undertook to provide a number of gauges for the district round Snowdon; for that district Mr. Symons provided gauges with cylinders rising 4 inches vertically from the edge of the cone of the funnel—these are called Snowdon rims, and funnels so provided are gradually displacing all others because they are so much better in time of snow. A gauge of this kind in copper is nearly indestructible, and independent of frost, because two vessels (one of glass and one of copper) must burst before the water can be lost.
Exhibited by L. P. CASELLA, F.R.Met.Soc.

22. **Symons's Galvanized Snowdon Gauge.** The special features of this gauge are that while it is accurate, and will last for 15 or 20 years, its cost is very small.
Exhibited by Messrs. NEGRETTI AND ZAMBRA.

MOUNTAIN RAIN GAUGES.

23. **Mountain Gauge.** This is the pattern adopted by Mr. Symons (see *British Rainfall*, 1867, p. 16), for rough mountain work, and for waterworks purposes in wet districts. It is capable of containing 48 inches of rain, and may be read off to tenths of an inch. It is constructed with much care, and all known sources of error (frost, evaporation, insplashing, &c.,) are guarded against. The rod is detached from the float (to avoid error from its intercepting the rain), and only dropped into the cup when an observation has to be made. The cross-piece enables the reading to be taken very accurately. The instrument has an outer cylinder to guard against frost and to facilitate emptying.
Exhibited by L. P. CASELLA, F.R.Met.Soc.
[As at the last moment a specimen could not be supplied an engraving was shown instead.]

24. **Engineers' or Waterworks Gauge.** This is identical in principle with the above, but modified to render it suitable for districts of which the mean annual rainfall does not exceed 40 inches. The inner vessel is only 5·658 inches in diameter, while the receiving surface is 8 inches, therefore the float rises two inches for each inch of rain—thus giving an open scale, which can be read to the hundredth of an inch, if desired. It will hold about 12 inches. *Exhibited by* L. P. CASELLA, F.R.Met.Soc.

25. **Symons's Small Mountain Gauge.** This is an attempt to provide a gauge accurate, low in price, frost resisting, holding 20 inches of rain, and easily read by shepherds, miners, and gamekeepers, as it is used chiefly in unfrequented mountain districts where it can be visited at long intervals only.
Exhibited by Messrs. NEGRETTI AND ZAMBRA.

26. **Bradford Waterworks Gauge,** designed by Mr. A. R. Binnie, C.E., for use on the gathering grounds of the Bradford Corporation: it has a Snowdon rim, a large copper pail to hold 17 inches of rain, and the measuring jar holds 1 inch instead of ½ inch as usual.
Exhibited by L. P. CASELLA, F.R.Met.Soc.

27. **Green's Mountain Rain Gauge.** This was designed by Mr. T. Green of Grasmere, for use on the Westmoreland Mountains: one is now at work there at an altitude of 2,860ft., it has two inner cans, so that if one burst the other will save the water, and the funnel is removable so that in winter there is ample room for snow.
Exhibited by Messrs. NEGRETTI AND ZAMBRA.

STORM GAUGES.

These are gauges not intended for general use, or for yielding continuous records, *for which they are not adapted*, but to enable observers to observe the most minute details of heavy rain during thunderstorms. Carefully attended to, they yield information of the very highest importance, both for architects and for engineers, as to the rate at which rain falls. With one of these instruments in London on June 23rd, 1878, rain was ascertained to be falling for 30 seconds at the rate of 12 inches an hour, or 288 inches a day.

28. **Symons's Storm Gauge**—*First Pattern.* In this a small funnel discharges into a tube, of which the diameter is so small that an inch of rain fills nearly 2 ft.; in the tube is a light ball of opal glass, this rises with the water, and can easily be seen against the black board even 10 or 20 ft. away. When the first tube is full, the overflow passes into a second, in which also there is a float, so that the record can be continued until two inches have fallen. The tubes are closed at the bottom by india-rubber tubes, and on the compress being removed the water escapes, the floats fall to the bottom, and the tubes being re-compressed, the gauge is ready for fresh observations. This gauge is broken if the least frost finds any water in it, and therefore it should be put out only during the summer months. The specimen is divided to show the rainfall on the metric system.
Exhibited by Messrs. NEGRETTI AND ZAMBRA.

29. **Symons's Storm Gauge**—*Second Pattern.* This is a much stronger and better instrument, but more expensive. The rain passes into a copper cylinder in which is a float, which rises as the rain falls. The float has a string passing round a pulley and kept tight by a counterpoise, therefore when the float rises, the pulley turns; at the extremity of the axle of the pulley there is fixed a hand like the minute hand of a clock, and the size of the parts is so arranged that this hand completes a revolution when 1 inch of rain has fallen. Inside the case there is very simple wheelwork whereby another short hand, like the hour hand of a clock completes a revolution for 5 inches. With this gauge it is therefore quite easy to read from a window the fall of rain to hundredths of an inch, and by doing this, say, every 30 seconds, the minutest detail of the fall of rain can be ascertained. Constructed by Messrs. Negretti and Zambra.
Exhibited by G. J. SYMONS, F.R.S.

REGISTERING AND RECORDING RAIN GAUGES.

30. **Crosley's Registering Rain Gauge.** The area of this gauge is 100 ins., and beneath the tube leading from the funnel, there is a vibrating divided bucket; when one compartment has received a cubic inch of water, *i.e.* 0·01 in. of rain has fallen, the bucket tips, the index advances on the first dial, and the other bucket begins to fill, and so on indefinitely.
Exhibited by Messrs. NEGRETTI AND ZAMBRA.

31. **East India Company's Modified Crosley Rain Gauge.** This differs from the Crosley chiefly in the recording arrangement. In place of the series of cog-wheels moving hands, the tipping bucket moves a weighted lever, which at each movement advances a graduated circle one division, the figures on the circle being read through a small opening in the side of the case. A small dial with a metal hand carries the record up to 100 ins.
Exhibited by G. J. SYMONS, F.R.S.

32. **Yeates's Electrical Self-Registering Rain Gauge.** The funnel is 100 square inches in area, and the measuring bucket (the working parts of which are made of platinum alloy with agate bearings) is adjusted to turn with one cubic inch of water. At each turn of the bucket electrical contact is made, and the index hand moves one division. The advantage of this instrument is that the funnel may be placed in any exposed position out of doors, while the registering part can be fixed indoors.
Exhibited by Messrs. YEATES AND SON.

33. **Stutter's Registering Rain Gauge,** with 24 collecting jars.
Exhibited by the KEW COMMITTEE.

34. **Beckley's Self-Recording Rain Gauge.** (See *Report of the Meteorological Committee*, 1869, p. 36.) *Exhibited by the* KEW COMMITTEE.

35. **Casella's Self-Recording Rain Gauge.** The recording portion only, as this instrument is sometimes used in a self-contained iron case standing on the ground, sometimes in a glass case in an observatory, the water being brought down by a pipe from a funnel above. The bucket becomes heavier as rain falls, and when 0·20in. has fallen it has drawn the pencil from one side of the cylinder to the other, the bucket tips and empties, and the pencil goes back to zero. In this pattern a shutter has been so arranged that any rain falling during the time the bucket is emptying is saved and allowed to pass into the next measurement.
Exhibited by L. P. CASELLA, F.R.Met.Soc.

36. **Richard's Self-Recording Rain Gauge. Float Pattern.** This consists of a funnel for collecting the rain and a pipe leading it into the reservoir in which there is a float. A style, carrying a writing pen, follows the motion of the float, rising 4 in. for a rainfall of 0·4 in. When the pen reaches the top of the revolving drum, the reservoir empties itself, the float falls to the bottom, and the pen returns to zero. The emptying of the reservoir is automatically obtained by a siphon, the starting of which is secured by an electro-magnet which, on the circuit of a battery being completed, pulls the float down and causes a sudden rise of the water-level, thereby filling up the siphon. *Exhibited by* MM. RICHARD FRÈRES.

37. **Richard's Self-Recording Rain Gauge. Balance Pattern.** This consists of a funnel and pipe leading the rain into a tipping bucket divided into two compartments and placed on a balance. One of these compartments being under the funnel, the rain falls into it and causes the balance to descend; a writing pen records this motion on the revolving drum. When the pen has reached the top (0·4 in. of rain) the tipping bucket reservoir oscillates, and the water filling the first compartment is emptied into a controlling reservoir. This motion causes the second or empty compartment of the bucket to place itself under the funnel. The filling and emptying of each compartment is alternately and automatically produced, and to each of these double operations corresponds a rise and a fall of the writing pen. *Exhibited by* MM. RICHARD FRÈRES.

FOREIGN RAIN GAUGES.

38. **French Rain Gauges.**—Rain gauge as supplied by the *Association Française pour l'Avancement de Science.* *Exhibited by* M. le Prof. MASCART.

39.——Side tube Rain gauge. During snow a night light or small lamp is placed upon the upper shelf to melt the snow and prevent the melted water from freezing and bursting the tube. *Exhibited by* M. le Prof. MASCART.

40. **Hervé-Mangon's Pluviomètre totaliseur.** The daily fall is read from the side tube, and then the water is passed into the large receiver, and the total is re-measured at the end of the month as a check on the daily readings. *Exhibited by* M. le Prof. MASCART.

41.——Ordinary gauge with receiver holding two inches of rain, to be drawn off by the tap at its base. *Exhibited by* M. le Prof. MASCART.

42. **Hellmann's Rain and Snow Gauge.** First pattern devised in 1883. The receiver and collector are combined, the latter having a stop cock. There are two vessels for changing the one for the other in winter when snow is falling. This pattern is now abandoned in Prussia, but is used in Alsace-Lorraine. *Exhibited by* Dr. G. HELLMANN.

43. **Hellmann's Rain and Snow Gauge.** Second pattern devised in 1886, and now used in the Prussian Meteorological Service. *Exhibited by* Dr. G. HELLMANN.

44. **Hellmann's Gauge for measuring the density of Snow.** *Exhibited by* Dr. G. HELLMANN.

45. **Wild's Rain Gauge, as used in Russia.** This consists of two cylindrical zinc vessels. The upper receiver is fitted with a brass rim to prevent possible loss by splashing. The water passes from the upper receiver through a kind of sieve into the lower vessel, and any air forced in with it escapes through the lateral turned up tube. The water in the lower vessel is let into a graduated glass by the tap. *Exhibited by the* METEOROLOGICAL COUNCIL.

46. **Colladon's Instrument for determining the Temperature of Hail.** *Exhibited by* Dr. W. MARCET, F.R.S.

47. **Nipher's Protected Snow Gauge.** (See *Report of the Chief Signal Officer, U.S.A.*, 1887, part 2., p. 384.) *Exhibited by the* KEW COMMITTEE.

MISCELLANEOUS RAIN GAUGES.

48. **4½-in. Tropical Rain Gauge.** The receiver of this gauge is large enough to hold 40ins. of rain. *Exhibited by* L. P. CASELLA, F.R.Met.Soc.

49. **Livingston's Rain Gauge.** This is a 3in. copper gauge with upright rim, copper receiver, and glass measure, as made for the late Dr. Livingston. *Exhibited by* L. P. CASELLA, F.R.Met.Soc.

50. **Marine Rain Gauge.** Mounted on gimbals for use on board ship. *Exhibited by* THE METEOROLOGICAL COUNCIL.

51. **Snow Melting Rain Gauge.** Invented by, and constructed for, Mr. James Sidebottom, F.R.Met.Soc. The case is double, warm water is poured into the angular tube, and when the snow (with which it is never in contact) in the funnel is melted the water is run off by the tap, and, if needed, a fresh supply is added. By this arrangement any mistake from adding a wrong quantity of water is impossible. *Exhibited by* J. SIDEBOTTOM, F R.Met.Soc.

52. **Snow Gauge.** *Exhibited by* E. MAWLEY, F.R.Met.Soc.

EVAPORATION GAUGES.

53. **Babington's Atmidometer.** This consists of an oblong hollow bulb of glass or copper, beneath which, and communicating with it by a contracted neck, is a second globular bulb, duly weighted with mercury or shot. The upper bulb is surmounted by a small glass or metal stem, having a scale graduated to grains and half-grains, on the top of which is fixed a shallow metal pan. The bulbs are immersed in a vessel of water having a circular hole in the cover through which the stem rises. Distilled water is poured into the pan above until the zero of the stem sinks to a level with the cover of the vessel. As the water in the pan evaporates, the stem ascends and the amount of the evaporation is indicated in grains. *Exhibited by* L. P. CASELLA, F.R.Met.Soc.

54. **von Lamont's Atmometer.** The evaporation pan is a shallow cylinder with a slightly curved bottom, from the middle of which a narrow pipe leads to a vertical cylindrical reservoir of water containing a closely fitting piston. The position of this piston in the cylinder is adjustable by means of a screw which moves the piston vertically, and it can be read by a vertical scale attached to the piston, a pointer being attached to the cylinder. The method of observing is as follows:—The piston is screwed up so as to allow the water in the evaporation pan to run into the reservoir, leaving the connecting tube just full, so that the water just makes the curved surface of the bottom of the pan continuous; the scale is then read and the water driven by the piston up to within a little of the top of the pan, and the evaporation allowed to take place, the piston is then raised so that the water sinks again from the pan to the same point as before, and the scale is read again. The difference of readings in scale divisions gives the depth of water evaporated. *Exhibited by* THE METEOROLOGICAL COUNCIL.

55. **Wild's Evaporimeter.** Evaporation takes place from a free surface of water, in a shallow cylindrical dish supported on the short arm of a lever balance. The longer arm, acting as a counterpoise, is provided with a pointer which moves over a graduated quadrantal arc, and the loss of weight, due to the evaporation of water from the dish, is indicated by the change in the position of the pointer on the scale. The diameter of the dish is 178 mm. (7 inches.) *Exhibited by* THE METEOROLOGICAL COUNCIL.

56. **de la Rue's Evaporimeter.** In this the water evaporates from a surface of moistened parchment paper, stretched over a shallow drum kept full of water, which is supplied from a cylindrical reservoir giving about 6ins. head. Into this vessel dips a narrow metal tube forming the only opening into a graduated cylinder of glass about 6ins. high and 1¼in. diameter. The glass cylinder is originally filled with water, and the tube leading from it, which dips into the reservoir, is perforated laterally. The water in the reservoir is therefore maintained at a constant level by a flow of water from the glass cylinder whenever the lateral opening becomes exposed to the air. The amount of water evaporated is given by the graduations on the glass cylinder, which are so drawn as to express the evaporation in hundredths of an inch. *Exhibited by* THE METEOROLOGICAL COUNCIL.

57. **Piche's Evaporimeter.**—This consists simply of a graduated cylindrical tube of glass closed at one end, and having the open end ground flat and covered by a disc of blotting paper about three times the diameter of the tube. This is kept in its place by a disc of the same diameter of the tube and attached to it by a spring. The instrument is hung vertically with the closed end upwards, so that as the water evaporates from the wet paper very small bubbles of air rise in succession to supply its place in the tube. The amount evaporated can be inferred from the scale engraved on the glass tube. *Exhibited by the* METEOROLOGICAL COUNCIL.

58. **Richard's Self-Recording Evaporation Gauge.** This consists of a pair of scales, one of which bears a basin of water or a plant. Weights are placed in the opposite scale to establish a state of equilibrium. A style is attached to the scale beam, and the pen records its motions on a revolving drum. The sensitiveness of the scale is regulated by a sliding weight, which being raised or lowered, raises or lowers the centre of gravity of the scale beam. *Exhibited by* MM. RICHARD FRÈRES.

59. **Evaporimeter, designed for use with growing Plants in a Botanical Laboratory.** A steel tape passes over a pulley resting on knife edges and supports the plant at one end and a counter-weight at the other. The pulley turns as the plant becomes lighter, moving a cup of mercury away from the mouth of a tube, and allowing the air to escape from the gas bag. The board resting on the bag falls and moves the pen ; it also increases the tension of a spring acting on the pulley ; this continues till the balance is restored and the mouth of the tube is again closed. The ordinates of the curve drawn are proportional to the change of weight. If the change of weight varies from negative to positive, a connection is made to the gas main to give a small continuous supply to the gas bag, or a simple arrangement in connection with the water main is used. *Exhibited by* THE CAMBRIDGE SCIENTIFIC INSTRUMENT CO.

60. **Apparatus used by the late Mr. G. Dines for measuring Evaporation.** A float is fixed on a centre at the bottom of the smaller vessel ; as the water in the larger vessel is lowered by evaporation, the float falls over and the quantity is measured upon the circular arc. The large vessel was immersed in water in a slate tank to within an inch of its rim. *Exhibited by* W. H. DINES, B.A., F.R.Met.Soc.

61. **Floating Rain Gauge and Evaporating Cup for ponds.** The instrument consists of a wooden float block, having two cavities in it holding a rain gauge and an atmometer, each removable at pleasure. The cavities communicate with the water underneath, in order to keep the gauges of the same temperature throughout. The evaporator has a louvre over it to keep out the sun's rays, but admits the wind through it. The rain gauge has a perforated diaphragm to keep out the sun's rays, and to prevent evaporation of the contents. The apparatus is intended to be floated out and moored in the centre of a piece of open water, and left there as long as suited to the state of the weather, and then drawn back again to shore. The gauges are then to be examined, and the quantities of water remaining ascertained by measuring glasses in the usual way. *Exhibited by* Surgeon-Major W. G. BLACK, F.R.Met.Soc.

62. **From the series of Evaporators constructed under the supervision of Mr. Rogers Field, C.E.,** and described in *British Rainfall* in 1889 :—

(1) The Fletcher evaporator, as arranged by the late Mr. Isaac Fletcher, M.P., F.R.S.
(2) The Watson evaporator, as designed by Dr. Dalton, F.R.S., and worked for nearly half-a-century by the late Mr. H. H. Watson, F.C.S.
(3) Miller's Wet sand evaporator.
(4) Tin evaporator.
(5) " with overflow.
(6) Casella's Can.
(7) " Bottle.
(8) Hook gauge, used for determining depth evaporated from the large tank, 6 ft. square and 2 ft. deep, which was used as the standard wherewith the foregoing and some other forms of instrument were compared.

Exhibited by G. J. SYMONS, F.R.S.

63. **Casella's 8 in. Pedestal Evaporator.**
Exhibited by L. P. CASELLA, F.R.Met.Soc.

INSTRUMENTS NOT PREVIOUSLY EXHIBITED.

64. **Self-Recording Apparatus for Wells, Rivers, Reservoirs, &c.** The action of the apparatus is briefly as follows :—A card which is fixed on a vertical drum is caused to rotate by clockwork, and a float on the surface of the water communicates its motion through a rack and pinion to a pencil, which thus shows, on a reduced scale, the variation in the level of the water. Besides its application as a tide-recording instrument, the apparatus can be used in conjunction with an overflow weir or notch for the purpose of gauging the flow of streams, in which case the diagram shows the depth of water flowing over the weir. It can also be applied to the fluctuation of water level in a well, and the yield of the well, to show whether that is influenced by pumping, and it can be made to furnish data for calculating the yield of a well which has been pumped down, by automatically recording the rate at which the well refills. The weight of the float and cord is counterpoised by a spring, and the vertical scale of the diagram can be varied at pleasure.
Exhibited by Baldwin Latham, Pres.R.Met.Soc.

65. **Helicoid Anemometer,** with helicoid fan 24 ins. by 5 ins., fitted with Dines' and Munro's patent arrangement for indicating at sight on a dial the velocity and pressure of the wind ; also mechanism to register up to 9,999 miles, and tenths and hundredths of miles.
Exhibited by R. W. Munro, F.R.Met.Soc.

66. **Robinson's Anemometer** with cups 5 inches diameter, fitted with Dines' and Munro's patent arrangement for indicating by a scale on a vertical glass tube the velocity and pressure of the wind.
Exhibited by R. W. Munro, F.R.Met.Soc.

67. **Helicoid Air Meter,** with 6 inch helicoid fan, registering up to 100,000 feet.
Exhibited by R. W. Munro, F.R.Met.Soc.

68. **Statoscope.** This is a very sensitive atmospheric barometer. The writing pen has a 13 millimetre (½ inch) stroke for each millimetre variation in the mercurial column. *Exhibited by* MM. Richard Frères.

69. **Anemo-Cinemograph.** This instrument indicates and registers the velocity of the wind in miles per hour, directly and without any calculation.
Exhibited by MM. Richard Frères.

70. **Self-Recording Aneroid Barometer,** going for a week and marking a dot on the paper every 15 minutes.
Exhibited by Mons. G. Meyer.

71. **Instrument for rendering apparent and measureable momentary oscillations of Atmospheric Pressure.**
Exhibited by A. E. Bennett.

72. **Early Pattern of Solar Radiation Thermometer** *in vacuo* with black glass bulb and certificate.
Exhibited by F. C. Bayard, LL.M., F.R.Met.Soc.

73. **Small Camera for Meteorological Photography,** showing a simple method of attaching a mirror of black glass for photographing meteorological phenomena.
Exhibited by A. W. Clayden, M.A., F.R.Met.Soc.

74. **Larger Camera for Photographing Clouds and Lightning.** The black mirror is finely-ground glass, blackened on the rough side. This apparatus is attached to a simply constructed stand, which can be clamped to a window-sill.
Exhibited by A. W. Clayden, M.A., F.R.Met.Soc.

75. **Frame for Measuring Cloud Pictures** for determining height and drift of clouds, designed by Gen. R. Strachey, F.R.S.. and Mr. G. M. Whipple, F.R.A.S. *Exhibited by the* Kew Committee.

PHOTOGRAPHS, &c.

76. **New York Blizzard of March 12-14, 1888.** Three Views.
Exhibited by H. P. Curtis.

77. **Self-Recording Rain Gauge** used at the Ufficio Centrale di Meteorologia, Rome. *Exhibited by* Prof. P. Tacchini.

78. **Flood at Rotherham Railway Station, May 15, 1886.** Two Views.
Exhibited by E. M. Eaton, F.R.Met.Soc.

79. **Flood on the Severn at Worcester, May 15, 1886.** Two Views.
Exhibited by G. B. Wetherall, F.R.Met.Soc.

80. **Rain Gauge Experiments. Photographs illustrative of Calne series.** First site of the experiments originated by Col Ward, F.R. Met. Soc., to determine (1) the effects of placing gauges at different heights above the ground, not (as had been done previously) on buildings, but on posts, and (2) to ascertain whether there is any difference in the indications of gauges ranging in diameter from 1 to 24 inches, and including square ones of 25 and 100 inches area. This photo shows the gauges as placed at Castle House, Calne, Wilts.
Exhibited by G. J. Symons, F.R.S.

81.——The same gauges removed to Strathfield Turgiss, Hants, in order to ascertain what effect, if any, local influences had in producing the results noticed at Calne. *Exhibited by* G. J. Symons, F.R.S.

82. **Rotherham Experimental Gauges.**—General view of the apparatus erected by Mr. Chrimes on the cover of Boston Reservoir, Rotherham, in order to study the diminution in the amount collected by gauges elevated above the ground, and its probable cause.
Exhibited by G. J. Symons, F.R.S.

83.———Weighing-machine used to ensure precision in the measurements in the preceding experiments. The beam turned readily with 0·001 in. It is shown with, and without, one of the collecting vessels.
Exhibited by G. J. Symons, F.R.S.

84.———Five mouthed gauge, part of the Rotherham series; it has one horizontal mouth and four vertical ones facing N.E.S. and W. respectively. From its records the altitude and azimuth whence any fall of rain comes can be computed. *Exhibited by* G. J. Symons, F.R.S.

85.———Forty-five degree gauge—of the same series—two views. In this gauge the funnel was set at an angle of 45°, and it was attached to a powerful vane which kept the orifice always in the azimuth of the prevailing wind.
Exhibited by G. J. Symons, F.R.S.

86.———Tipping gauge of same series—two views. In this case the funnel was not only kept in the azimuth of the prevailing wind, but it was also by the lateral fans so tipped as also to meet its angle in altitude.
Exhibited by G. J. Symons, F.R.S.

87.———Three views of the same gauges as re-erected on the bank of Ulley Reservoir, Rotherham, in order to compare results with those in their former position. *Exhibited by* G. J. Symons, F.R.S.

88. **Chester Lead Works.**—Shot Tower of Lead Works, Chester, 160ft. high, used as one (of many) stations for determining decrease of rainfall with elevation above the ground. *Exhibited by* G. J. Symons, F.R.S.

89. **Boston Church, Lincolnshire,** the tower of which is 273ft. high. Observations have been made on this tower for determining the decrease of rainfall and of temperature with elevation above the ground. (Two views.)
Exhibited by the Royal Meteorological Society.

90. **Latham's Self-Recording Rain Gauge.** The rainfall accumulating in the gauge (by means of a float) actuates a pencil on the diagram on a vertical

drum which is driven continuously by clockwork. The record thus obtained shows not only the total amount of rain which has fallen in a given time, but the rate at which it falls. (Three views.)

Exhibited by BALDWIN LATHAM, Pres. R.Met.Soc.

Floods, damage by—

91. ———Two photos of Todmorden flood, July 1870.

92. ———Hereford Railway Station in the flood of 1875.

93. ———Valley House, Chepstow, showing lawn nearly covered with stones washed down from above.

94. ———Sheet of views of Chelmsford flood, August 2nd, 1888.

95. ———Three views of Bristol floods, March 1889.

Exhibited by G. J. SYMONS, F.R.S.

96. **Sites of Rain Gauges in the Lake District.** *Cumberland*—(1) Stye Head Tarn ; (2) Stye Head Pass ; (3) The Borrowdale valley looking south ; the Stye (probably the wettest spot in the British Isles) is near the centre of the photo, and Seathwaite hamlet is just behind the trees further to the west ; (4) Watendlath Tarn ; (5) Grange at the foot of Derwentwater—summer, looking south ; winter, looking south-west ; (6) Buttermere, the gauge is at Hassness near the edge of the lake; (7) General view of Derwentwater with Keswick in the foreground.

Exhibited by G. J. SYMONS, F.R.S

97. **Ben Nevis Observatory**—(1) A clear day ; (2) too much hoar frost for the anemometer. *Exhibited by* G. J. SYMONS, F.R.S.

98. **Specimens of Cloud Photographs** taken on ordinary Ilford plates by reflection from black mirrors.

Exhibited by A. W. CLAYDEN, M.A., F.R.Met.Soc.

99. **Photographs of Clouds taken at the Santis Observatory, Switzerland,** in 1890. *Exhibited by* Prof. A. RIGGENBACH.

100. **Photograph of the Tower of the Winds, Athens.**

Exhibited by Dr. C. T. WILLIAMS, M.A., F.R.MetSoc.

101. **Models of Hail-Stones,** 7ins. in circumference, which fell near Montereau, France, on August 15th, 1888. (See *Quarterly Journal of the Royal Meteorological Society*. Vol. XV. p. 47.)

Exhibited by the ROYAL METEOROLOGICAL SOCIETY.

MAPS AND DIAGRAMS.

102. **Map of Rainfall of part of Great Britain** prepared by the late Mr. J. Atkinson, of Carlisle, and issued March 1840. (Believed to be the first map of any part of the British Isles showing the Rainfall.)

Exhibited by G. J. SYMONS, F.R.S.

103. **Map of Rainfall over the British Isles,** prepared by the late Mr. Keith Johnston. *Exhibited by* G. J. SYMONS, F.R.S.

104. **Map of Rainfall over the British Isles,** based on the average 1860-65, prepared for the *Sixth Report of the Rivers Pollution Commissioners*, by Mr. G. J. Symons. *Exhibited by* G. J. SYMONS, F.R.S.

105. **Map showing the Stations** from which a record of the fall of rain in the British Isles was quoted in *British Rainfall* 1889.

Exhibited by G. J. SYMONS, F.R.S.

106. **Map showing the sites of the Rain Gauges** on the Manchester, Sheffield, and Lincolnshire Railway. *Exhibited by* THE M. S. & L. R. Co.

107. **Statement of Rain** fallen in the year 1890, at the Stations of the Manchester, Sheffield, and Lincolnshire Railway.
Exhibited by THE M. S. & L. R. Co.

108. **Map of Rainfall of Europe**, prepared by Prof. Otto Krummell.
Exhibited by G. J. SYMONS, F.R.S.

109. **Map of Rainfall of France**, prepared by M. Angot.
Exhibited by G. J. SYMONS, F.R.S.

110. **Rainfall Atlas of Russia**, prepared by Dr. Wild.
Exhibited by the ROYAL METEOROLOGICAL SOCIETY.

111. **Map of Rainfall of India**, prepared under the direction of Mr. H. F. Blanford, F.R.S. *Exhibited by the* ROYAL METEOROLOGICAL SOCIETY.

112. **Map of Rainfall over the S.E. of Australia and Tasmania** during 1884, published by the proprietors of *The Australasian.*
Exhibited by G. J. SYMONS, F.R.S.

113. **Map of Rainfall of South Australia** in 1887, by Mr. C. Todd, F.R.S.
Exhibited by G. J. SYMONS, F.R.S.

114. **Rainfall Map of New South Wales** for 1889, by Mr. H. C. Russell, B.A., F.R.S. *Exhibited by the* ROYAL METEOROLOGICAL SOCIETY.

115. **Rainfall Chart of the United States.** By Mr. C. A. Schott.
Exhibited by the ROYAL METEOROLOGICAL SOCIETY.

116. **Map of Mean Annual Rainfall of the Globe**, by Prof. E. Loomis.
Exhibited by the ROYAL METEOROLOGICAL SOCIETY.

117. **Record from Osler's Anemometer** at the Royal Observatory, Greenwich, showing Rainfall for July 4-5, 1890, and corresponding Photographic Record from Thomson's Electrometer.
Exhibited by W. H. M. CHRISTIE, F.R.S., Astronomer Royal.

118. **Diagrams of Barometer, Thermometer, Rain, and Wind,** at Barrow, 1876-9, Kenilworth, 1880-8, and Beckford near Tewkesbury, 1884-90.
Exhibited by F. SLADE, F.R.Met.Soc.

119. **Sheet and Album of Engravings of Self-Recording Rain-Gauges.**
Exhibited by G. J. SYMONS, F.R.S.

120. **Waterspouts.** Early lithograph of "Phénomène de Trombes Marines observé dans la mer de Sicile en vue de Stromboli le 27 Juin, 1827, et dessiné par L. Mazzara à bord du Brigantin le Portia, Captain Cabbage, au moment ou le navire fait feu sur la trombe qui le menaçait le plus près."
Exhibited by G. J. SYMONS, F.R.S.

121. **Rothamsted Rain Gauges.**—Coloured Drawing, by Lady Lawes, of the Rothamsted Rain-gauges. For the purposes of accurate measurement of the rain, and of obtaining sufficient quantities for analysis, a large gauge of one-thousandth of an acre area has been in use since the beginning of 1853; also an ordinary funnel-gauge of 5 ins. diameter; and these are represented in the drawing. An 8 inch "Board of Trade" copper-gauge has also been in use since January, 1881. The funnel portion of the large gauge is constructed of wood, lined with lead; the upper edge consisting of a vertical rim of plate glass bevelled outwards. The rain is conducted by a tube into a galvanised iron cylinder underneath, and when this is full it overflows into a second cylinder, and so on into a third and fourth, and finally into an iron tank. Each of the four cylinders holds rain corresponding to half-an-inch of depth, and the tank an amount equal to 2 inches. Each cylinder has a gauge-tube attached, graduated to read to ·002 in., but which can be read to ·001 in. Small quantities are transferred to a smaller cylinder with a gauge-tube graduated to ·001, or one-thousandth of an inch.
Exhibited by Sir J. B. LAWES, Bart., and J. H. GILBERT, LL.D., F.R.S.

122. **Rothamsted Drain (or Percolation) Gauges.**—Coloured drawing by Lady Lawes of the Rothamsted Drain-gauges. The three "Drain-gauges," each one-thousandth of an acre area, for the determination of the quantity and the composition of the water percolating respectively through 20 inches, 40 inches, and 60 inches depth of soil (with the sub-soil in its natural state of consolidation), have been in use since September, 1870,—that is for a period of more than 20 years. The gauges were constructed by digging a deep trench along the front, gradually undermining at the depth required, and putting in plates of cast iron (with perforated holes) to support the mass. The plates were then kept in place by iron girders, and the ends of the plates and of the girders supported by brickwork on three sides. Trenches were then dug round the block of soil bit by bit, and it was gradually enclosed on each side by walls of brick laid in cement. Below the perforated iron bottom a zinc funnel of the same area as the soil was finally fixed, and the drainage water is collected and measured in galvanised iron cylinders with gauge tubes, as in the case of the rain.
Exhibited by Sir J. B. LAWES, Bart., and J. H. GILBERT, LL.D., F.R.S.

123. **Table of Rainfall and Drainage at Rothamsted** for the 20 harvest years ending August 31st, 1890.
Exhibited by Sir J. B. LAWES, Bart., and J. H. GILBERT, LL.D., F.R.S.

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124. **Rothamsted Rain Gauges,**—Cylinders of the $\frac{1}{1000}$ acre rain gauge, with side tube attached, reading to ·002inch.
Exhibited by Sir J. B. LAWES, Bart., and J. H. GILBERT, LL.D., F.R.S.

G. J. SYMONS, F.R.S. } *Secretaries.*
JOHN W. TRIPE, M.D. }
WILLIAM MARRIOTT, *Assistant Secretary.*

PROCEEDINGS AT THE MEETINGS OF THE SOCIETY.

MARCH 18th, 1891.

Ordinary Meeting.

C. THEODORE WILLIAMS, M.A., M.D., Vice-President, in the Chair.

HORATIO BREVITT, The Leasowes, Tettenhall Road, Wolverhampton;
JOHN LOVEL, York Road, Driffield; and
LYALL GEORGE OLIVER, M.A., B. Sc., Grammar School, Newark,
were balloted for and duly elected Fellows of the Society.

Mr. SCOTT stated that the subscriptions promised towards the New Premises Fund amounted to £1,141 8s., and that the Council had taken three rooms on the second-floor at 22 Great George Street, to which the Library and Office would shortly be removed.

The following Paper was read :—

"A CONTRIBUTION TO THE HISTORY OF RAIN GAUGES." By G. J. SYMONS, F.R.S. (p. 127.)

Mr. A. W. CLAYDEN, M.A., F.R.Met.Soc., exhibited (by means of a lantern) a large number of slides illustrating Meteorological Phenomena (p. 142.)

On the motion of Mr. SILVER, seconded by Mr. LECKY, the thanks of the Society were given to the Exhibitors for the loan of their Instruments, &c.

The Meeting was then adjourned in order to afford the Fellows an opportunity of inspecting the Exhibition of Rain Gauges, Evaporation Gauges, &c., which had been arranged in the rooms of the Institution of Civil Engineers (p. 180).

APRIL 15th, 1891.

Ordinary Meeting.

ARTHUR BREWIN, Vice-President, in the Chair.

JOSEPH BAXENDELL, The Observatory, Birkdale, Southport;
HENRY CHAMP, Manchester; and
SAMUEL HARTSHORNE RIDGE, B.A., F.R.G.S., 275 Victoria Parade East, Melbourne,
were balloted for and duly elected Fellows of the Society.

The following Papers were read:—

"ON THE VARIATIONS OF THE RAINFALL AT CHERRA POONJEE IN THE KHASI HILLS, ASSAM." By HENRY F. BLANFORD, F.R.S. (p. 146.)

"SOME REMARKABLE FEATURES IN THE WINTER OF 1890-91." By FREDERICK J. BRODIE, F.R.Met.Soc. (p. 155.)

"THE RAINFALL OF FEBRUARY 1891." By H. SOWERBY WALLIS, F.R.Met.Soc. (p. 167.)

"SOUTH-EAST FROSTS, WITH SPECIAL REFERENCE TO THE FROST OF 1890-91." By the Rev. FENWICK W. STOW, M.A., F.R.Met.Soc. (p. 176.)

"SNOWSTORM OF MARCH 9TH AND 10TH, 1891, AT SHIRENEWTON HALL, CHEPSTOW." By E. J. LOWE, F.R.S. (See below.)

CORRESPONDENCE AND NOTES.

GREAT SNOWSTORM, MARCH 9TH AND 10TH, 1891, AT SHIRENEWTON HALL, NEAR CHEPSTOW. By E. J. LOWE, F.R.S., F.R.Met.Soc.

THE late snowstorm and gale in this neighbourhood was a marked example of blizzard. There were series of limited areas where a large amount of snow collected, and this snow for the most part had previously fallen, and was again blown from the fields, moving along near the ground until meeting with an obstruction, and then becoming mingled with the snow already gathered there, causing a dense cloud of snow-dust, the snow being broken up into such minute fragments that it more nearly resembled flour than snow.

Driving from Chepstow on Tuesday the 10th, at 4 p.m., I had the opportunity of a close examination. My carriage became firmly embedded in a deep snow drift (varying from 6 to 8 ft. high) before being aware that there was an impenetrable mass of snow close by. A drift could be seen extending half across the road, but at a few yards further on, the blowing snow became so dense that objects at more than the distance of two or three feet were invisible. This snow-dust was forced into, and penetrated, clothes, covering them as if with flour instead of snow, and it could not be shaken off like ordinary snow. It was impossible to face the blizzard, the head had to be turned away from the direction in which the gale was blowing. As there was a narrow open space close to the

opposite hedge, I walked through the whole length (about 50 yards), and at either end the prospect was clear enough to see a distance of two or three miles, even when quite close to the blizzard, the boundaries being so sharply defined.

There were many such drifts in this neighbourhood varying from 30 to more than 100 yards, and the snow in them was so solidly pressed down that, when cut through, the spadesfull thrown out did not fall to pieces. Nearly every place was snowed up for several days, and it was only possible to force a passage on foot after the gale had ceased, for during its continuance it was extremely dangerous to make the attempt. At the worst part of the gale very little snow was actually falling, but the air was full of snow-dust blown from exposed situations until no snow remained in the fields except along the hedges, and where the gale passed across ploughed fields the drifts were much discoloured owing to the large amount of soil that was blown from the fields with the snow.

Roofs of houses facing the gale (*i.e.* North-east) had the snow blown under the slates until in some houses it was 3 ins. deep.

Within the blizzard the cold was intense, apparently much more so than on either side without these drifts.

The clouds of snow moved close to the ground, and, as it were, boiled over the obstructions, at the same time stirring up the snow that had been previously deposited.

It has been very difficult to ascertain what amount of snow fell, as most of it was shifted by the gale. It could only be done in sheltered situations where trees were on the north-east side, and even only approximately with these precautions. The depth of the snow was measured along a line 28 yards in length, situated to the south-west of a plantation of trees and commencing 20 yards from the trees; at the end of this line nearest to the trees was drift snow, and at the other extreme a portion had been blown away.

North-East.

Measured on Thursday.		Measured on Tuesday Afternoon.
$4\frac{1}{4}$ inches		14 inches deep.
$3\frac{1}{2}$,,		12 ,,
3 ,,		10 ,,
$2\frac{1}{8}$,,		8 ,,
	×	....................A.
$2\frac{1}{4}$,,		7 inches deep.
$1\frac{3}{4}$,,		$5\frac{1}{2}$,,
$1\frac{1}{2}$,,		$4\frac{1}{2}$,,
1 ,,		3 ,,

South-West.

At the point A the depth at 7 a.m. on the 10th was 6 ins., and this was increased in the afternoon to $7\frac{3}{4}$ ins. From near this place the snow was gathered on Thursday at 6 p.m. and melted, it having at that time sunk to $2\frac{1}{8}$ ins., and though the surface had somewhat melted, the water had not passed through the snow. The actual amount when melted was 0·672 in.

To show the difficulty, the ordinary 8 in. rain gauge only caught 0·004 in., a snow gauge 0·120 in., and a second one 0·122 in., whilst a third at 7 a.m. on the 10th (after 6 ins. of snow had fallen, *i.e.* 0·504 of an inch) was placed at an angle of 45° towards north-east, and this collected 1·075 ins., whilst not more than 0·168 in. could have fallen; $\frac{9}{10}$th being due to blown snow. Hollows in the ground were filled up with the driving snow so that a sunken gauge with the top level with the ground would have been quite full of snow-dust.

At Ilton Court	melted snow	0·950 in.	depth 8 ins.
,, Piercefield Park	,,	0·400 ,,	,, 4 ,,
,, Dennel Hill	,,	0·340 ,,	,, $4\frac{1}{2}$,,

The above are all to north-east, and situated 1, 3 and 4 miles distant.

Snow commenced falling at 4 p.m. on the 9th, with a North-east gale, and ceased at 6 p.m. on the 10th, when the gale was over, and it became frosty.

The barometer had been falling from the 4th, but began to rise again at 2 a.m.

TEMPERATURE.

March.	Read at 9 a.m.		Read at 6 p.m.			Mean Temp.	Rain.
	Min. 4 ft.	Min. on Grass.	Max. in Shade 4 ft.	Max. in Sunshine 4 ft.	Max. Sun Vacuum Therm.		
	°	°	°	°	°	°	In.
8	34·3	36·1	40·3	41·0	46·0	35·7	·403
9	29·5	26·9	36·6	43·0	48·0	31·0	·007
10	25·0	26·8	39·0	40·0	40·0	29·2	·372
11	23·0	25·0	43·1	59·0	72·8	31·5	·300
12	21·5	19·0	42·3	59·0	67·0	31·1	..
13	30·4	28·9	43·4	53·3	67·0	34·4	..
14	30·9	32·1	37·8	38·5	43·1	33·1	·005
15	26·2	22·0	44·8	55·3	71·9	35·0	·634
16	33·1	29·3	46·4	55·8	82·7	36·7	·097

on the 9th, falling again in the afternoon. The wind, which had been South-west and West-south-west, became North on the morning of the 8th, and North-east on the morning of the 9th, South-south-west on the 15th, with much snow from 1.15 p.m. till 8 p.m., and heavy rain after 9 p.m. The wind on the 16th became South-east.

Barometer (corrected and reduced to sea-level).

		Ins.
6th.	2 a.m.	30·201
7th.	2 ,,	29·818
8th.	2 ,,	29·687
9th.	2 ,,	29·770
10th.	2 ,,	29·488

9th fell gently till 9 p.m.

	In.
From 9 p.m. to 10 p.m. fell	·05
10th, from 2 a.m. till 3 a.m. fell	·03
3 ,, 4 ,,	·04

Then very steady till 10 a.m.

From 10 a.m.	till	11 a.m.,	fell	·10
,, 11	,,	noon	,,	·08
,, noon	,,	1 p.m.	,,	·01
,, 1	,,	2 ,,	,,	·01
,, 2	,,	3 ,,	,,	·01
,, 3	,,	4 ,,	,,	·01
,, 4	,,	5 ,,	,,	·01

And then almost stationary till midnight.

It ought to be explained that the prospect was visible for several miles, owing to the situation being higher than the surrounding country. There were numerous drifts, but they were at a lower level and could be looked over. *All* roads lower than the surrounding fields were filled up with snow.

SOLAR HALO SEEN AT COOPER'S HILL, STAINES, ON JUNE 9th, 1891. By Prof. HERBERT MCLEOD, F.R.S.

A SOLAR halo of an unusual form was observed here on Tuesday, June 9th. At about 9.15 a.m. an elliptical arch was seen over the sun, the highest portions of the arch being brightly coloured, and the sides white and only just visible at about the level of the sun; nothing was seen below the sun. Having to lecture on that morning, I asked Mr. Appleyard, Professor Stocker's Assistant, to measure the halo with a sextant, and at 10.20 a.m. he observed a small portion of the halo

below the sun, but which lasted only a short time. The measurements from the sun to the halo above and below were 21°46′, making the minor axis 43°32′. The measurements from the sun to the halo horizontally were 28°15′, or the major axis subtended 56°30′. The halo afterwards appeared to become more circular, but clouds prevented measurements being taken.

TEMPERATURE AND AREA. Note by E. G. ALDRIDGE, F.R.Met.Soc., F.G.S.

IT is the invariable practice of meteorologists, in calculating the mean temperature of the British Islands from the mean temperatures of the three constituent kingdoms, to assume for these kingdoms equal areas, or rather to overlook the important fact that these three great divisions are not of equal size. Thus, taking Great Britain alone, if the mean temperature of any given period be 50° in England and 40° in Scotland, the mean temperature for the entire island would not be 45°, but about 46½°.

THE DESTRUCTIVENESS OF TORNADOES.

AT the request of the Chief Signal Officer, Prof. H. A. Hazen has made an inquiry into the average number of Tornadoes in the United States, the area devastated by them, and the number of lives lost annually.[1]

In investigating tornadoes, great difficulty was experienced in accurately determining property losses or loss of life, the difficulty resulting from exaggerated reports which are invariably spread over the country in connection with public calamities of this kind. For instance, the Louisville tornado of March 27th, 1890, was months later reported by the public press to have caused a loss of 500 lives instead of 135—the true number. Prof. Hazen divided the tornadoes into three classes: first, violent storms causing destruction; third, the most severe tornadoes; and placed in the second class all other known violent storms. While there were about one thousand tornadoes, each, in classes 1 and 2, causing the death of 1,071 people, an average of one person to two storms, and a loss of about $23,000,000 in property, yet there were but 58 tornadoes of a very violent character, killing 755 people and destroying property to the amount of $11,894,700, an average loss of 13 lives and over $200,000 of property to each storm of class 3.

Several methods of determining the average destructive area covered by tornadoes were tested. In one case the result gives the relation between the total area visited annually by violent storms of all classes to the area of the state, with the following result: In Alabama, one square mile of *limited* destruction annually to each 7,866 square miles; Arkansas, one to 14,418; Georgia, one to 6,696; Illinois, one to 8,172; Indiana, one to 6,210; Iowa, one to 7,164; Kansas, one to 9,720; Michigan, one to 18,896; Missouri, one to 6,336; Ohio, one to 4,554; Pennsylvania, one to 9,972; Wisconsin, one to 12,042. These figures, of course, are not strictly comparable, especially when we consider the state of Ohio, which has a very large number of intelligent voluntary observers, on the one hand, and Kansas, on the other, a state not thickly settled in all sections.

Another plan followed was to consider the area of destruction covered in all well-studied and *destructive* tornadoes, and then apply that area by weight to all violent storms of each state. The following table shows the relative numbers; Alabama, one square mile of devastation or *severe destruction* to each 480,600 square miles; Arkansas, one to 712,800; Georgia, one to 504,000; Illinois, one to 185,400; Indiana, one to 330,000; Iowa, one to 432,000; Kansas, one to 436,500; Michigan, one to 914,400; Missouri, one to 406,800; Ohio, one to 243,000; Pennsylvania, one to 468,000; Wisconsin, one to 475,900. These results are materially different from those first given, and they appear more satisfactory. Such methods of comparing destroyed with undestroyed areas are, of course, incomplete, and must be received with caution.

It appears from these data that in no state may a *destructive* tornado be expected oftener, on an average, than once in two years, and that the area over which the

[1] *Report of the Chief Signal Officer*, U.S. War Department, 1890.

total destruction can be expected is exceedingly small even in the states most liable to these violent storms. Prof. Hazen's figures regarding the relation of destruction by fire to that of tornadoes are interesting, and worthy of consideration.

The Chief Signal Officer believes this matter of great public importance, and desires to impress upon the people at large how small are the chances of personal injury or loss of property in this connection.

It is well settled, however, that in the last eighteen years the death casualties from tornadoes average 102 annually. While this is a large number, yet it does not appear to be as great as that of the death casualties from lightning, since during the year 1890, from March to August inclusive, there were 102 lives lost by lightning, and in compiling this latter record the list is incomplete, especially as regards the Southern States. It may be safely assumed that, dangerous as are tornadoes, they are not so destructive to life as thunderstorms.

RAINFALL OF THE PACIFIC SLOPE AND THE WESTERN STATES AND TERRITORIES.

GEN. GREELY, the Chief Signal Officer, recently submitted to the United States Senate a Report on the Rainfall in Washington Territory, Oregon, California, Idaho, Nevada, Utah, Arizona, Colorado, Wyoming, New Mexico, Indian Territory, and Texas, together with 15 charts, and the corresponding data, showing the maximum and minimum for the year and the mean rainfall for each month of the year. This is also accompanied by a report by Lieut. W. A. Glassford, on the causes of the wet and dry seasons, the abundance and deficiency in different portions, the summer rainy season in Arizona, &c.

Lieut. Glassford says :—

"The season of rain occurrence notably varies in different portions of the Pacific slope. In California, Oregon, and Washington there is a marked dry season during the summer, which lengthens in duration to the southward. In Arizona there are two rainy seasons, one in midsummer, the other during the colder portions of the year. Between the Rocky and Sierra Nevada ranges of mountains the rainfall is rather uniform, but with an increasing tendency during the winter.

"That part of the Pacific slope west of the Sierra Nevada and Cascade ranges is the most highly favoured with rain. As seen in the charts the most noteworthy peculiarity is the summer drought. Summer showers and thunderstorms occur, however, in the mountain regions of Northern California, also in Oregon and Washington west of the Cascades. There is a general increase in frequency of summer rains from south to north, and the drought shortens in duration in the latter direction.

"Frequently not a sprinkle of rain falls in the Sacramento or San Joaquin Valleys, nor in the Southern Counties, from May to October. This periodic division of rainy and dry weather during the year has brought into use the term 'wet and dry season,' and references to rainfall measurements are generally understood to commence with the rainy season, and the term seasonal instead of annual is invariably the current estimate. In the great valley of California the expectation of rainless summers admits of the uninterrupted cereal harvest, its sacking and shipment, to be made without fear of damaging rains. It is an ordinary sight, during the harvest season and after, to see millions of bushels of grains sacked and piled without shelter in fields or on open cars.

"The system of mountains and valleys in Oregon and Washington Territory being similar to the district just discussed, the rainfall differs but little except in amount. There is distinctly a wet and dry season west of the Cascades, as well as in California. The wet season is characterised by either downpours or drizzly weather, and the dry seasons by scattered showers. The periodic feature of rains continues near Vancouver Island, and northward in a lesser degree, for at Sitka the rain is nearly equally distributed throughout the year.

"In the plateaus of Arizona the rainy season comes in the summer months."

Gen. Greely in his Report says :—

"An examination of the charts of maximum annual rainfall and minimum annual rainfall of these regions shows clearly that rainfall conditions are con-

siderably more equable than has been generally believed, so that the isohyetal lines are quite as regular on these charts of maxima and minima conditions as on those of average conditions. The minimum rainfall has never reached zero for any year, and annual or seasonal rainfalls less than one inch have occurred in South-western California and South-western Arizona at few stations only. These maps of maxima and minima precipitation must be of great practical value, as showing the settler or investor exactly the extreme conditions which he must expect to experience in these regions.

"It is well known that enormous quantities of water occasionally fall in these arid regions, the phenomena being known as "cloud-bursts." These downpours of rain, while injurious and even destructive at the time, yet being taken up by the earth, they serve usefully later as a water supply, through the medium of rivers, artesian wells, or springs. The quantities which fall in a single cloud-burst cannot be calculated, but the amount can be expressed by no other word than enormous. In South-eastern California, in the desert country, where it has been said that no rain falls, one cloud-burst was of such extent that, although the country was nearly level, yet water fell in such enormous quantities that over a quarter of a mile of the Southern Pacific Railroad was completely swept away, and other portions of the track submerged and damaged. It is to be noted also that this quantity of rain fell during one of the dry months, when the rain-map showed for Southern California only ·01 or ·02 in. of rain, barely enough to moisten the surface of the sandy desert.

"The question of increasing rainfall in the Great Interior Basin seems to be satisfactorily settled as far as the catchment basin of Great Salt Lake is concerned. The systematic and careful observations made by Prof. G. K. Gilbert, of the Geological Survey, supplemented by other data for the past forty years, which he has collated and sifted, gives with tolerable accuracy the level of the Great Salt Lake, which serves as a reservoir for probably two-thirds of the entire territory of Utah, as well as for a considerable portion of Idaho. A chart kindly furnished by Prof. Gilbert shows that Salt Lake fell from 1845 to 1849; rose to 1856, fell to 1860; rose to 1873, and fell, with a slight interruption, until 1884, and rose until 1886, since which time it has a slightly falling tendency. It is significant that while the first two minima were substantially the same in 1849 and 1860, yet the minimum of 1884 is at about the same height as the maximum of 1856, and is over a foot above the maximum of 1845. As the country adjacent to the lake is substantially level, it follows that any increase in the height of the water must be most gradual, since the area of the lake, and consequently the evaporating surface of water, is largely increased. This consideration would not be so important in some portions of the United States, but in a region where the annual evaporation cannot be far from 6 or 7 ft., it is a very pertinent fact.

"The changes in the level of Salt Lake are perhaps best shown by five-year periods, beginning with 1845. The elevation above zero (lowest water-level) for five-year periods is as follows:—

	Ft.		Ft.		Ft.
1845 to 1849	2·1	1860 to 1864	3·6	1875 to 1879	11·5
1850 to 1854	3·4	1865 to 1869	9·6	1880 to 1884	6·4
1855 to 1859	5·2	1870 to 1874	12·6	1885 to 1887	8·2

"It is a significant fact, which may, however, be overrated, that the greatest and most rapid rise of the water of Salt Lake occurred between the years 1862 and 1870, that is to say, during the period when the amount of land being brought under cultivation and the quantity of vegetation and the number of trees were most largely increasing. This increase of height in Great Salt Lake continued, too, despite the fact that irrigation canals were being brought into extensive use, so that large quantities of water which otherwise would have run into the lake were diverted to watering the irrigable (sic) lands, and were absorbed by the soil or evaporated in the dry air of that region."

RECENT PUBLICATIONS.

AMERICAN METEOROLOGICAL JOURNAL. Vol. VIII. Nos. 1-2. May and June 1891. 8vo.

Contains, among other articles, the following information:—Cold Waves: by Prof. T. Russell (8 pp.).—Parhelia and Paraselenæ at Grand Forks, North Dakota: by Prof. L. Estes (2 pp.).—How could the Weather Service best promote Agriculture?: by Prof. M. W. Harrington (8 pp.).—Is the Influenza spread by the wind?: by Dr. H. H. Hildebrandsson (5 pp.). The result of the author's investigation is that the influenza is propagated by infection, and conducted from place to place through human circulation, and that the time of incubation is two to three days. The state of the weather seemed to have had no influence on this sickness. In fact the influenza raged with the same severity in countries possessing very different climates, and during very different weather conditions.—An ink recorder for the electrical anemometer: by S. P. Fergusson (2 pp.).—A brief notice respecting Photography in relation to meteorological work: by G. M. Whipple (6 pp.).—Application of Photography to meteorological phenomena: by W. Marriott (7 pp.). These two papers have been reprinted from the *Quarterly Journal of the Royal Meteorological Society*, Vol. XVI., July 1890.—New England Meteorological Society (20 pp.). This gives the papers read at the meeting held on April 18th, 1891, when the subject for discussion was Weather Prediction.—Weather Prediction in the States and its improvement: by M. W. Harrington (10 pp.).—Farwell's Rainfall scheme (7 pp.).

BIHANG TILL KONGL. SVENSKA VETENSKAPS-AKADEMIENS HANDLINGAR. Band XVI., Afd. 1. No. 5. 1891. 8vo.

Contains: Études des conditions météorologiques à l'aide de cartes synoptiques representant la densité de l'air: par N. Ekholm (36 pp. and 18 plates). Dr. Ekholm has traced for a number of days lines which he now calls *isodenses*, representing the density of the air calculated according to a formula which he gives. He finds, speaking generally, 1. That the isodenses run parallel to the coasts. 2. That whenever a depression exists the rarefied air is found to the south and east of the centre, and the dense air to the north and west. If these are not strongly marked the depression has slight intensity, and *vice versâ* when they are strongly contrasted. 3. If a contrast between densities of the air in districts close to each other appears, a depression will be found there. This was notably the case in the cyclone of October 24th, 1882, which appeared suddenly over the Channel, and Dr. Ekholm gives other similar examples from Scandinavia. He finds, as regards probable direction of advance of depressions, that it is generally the case that they advance along the tangent to the isobars at the point where the gradient is steepest, and in the direction of the wind there. If the isobars are uniformly distributed round the centre, it will be found that the cyclone will advance along the isodenses, leaving the rarefied air on its right-hand side.

CYCLONE MEMOIRS. Part III. Published by the Meteorological Department of the Government of India, under the direction of J. ELIOT, M.A., Meteorological Reporter. 1890. 8vo. 165 pp. and 29 plates.

This contains an account of the cyclonic storm of September 18th to 20th, 1888, and of the cyclone of October 27th to 31st, in the Bay of Bengal; and the cyclone of November 6th to 9th, 1888, in the Arabian Sea. Mr. Eliot says that the following appear to be some of the more important inferences with regard to the constitution and motion of the cyclonic storms, and, therefore, probably of cyclones generally in the Indian area:—1. That the winds differ considerably in intensity in different quadrants, and that this difference is mainly caused by the fact that the humid winds which maintain the vigorous circulation of the cyclone enter mainly in one quadrant. 2. The amount of ascensional movement or uptake differs very considerably in different quadrants, and is usually most rapid and vigorous in the advancing quadrant at some little distance in front of the centre. 3. In consequence of ascensional motion and rainfall taking place most vigorously in the advancing quadrant, or in front of the cyclone, the isobars

are oval in form, and the longest diameter coincides approximately with the direction of the path of the centre. The centre of the cyclonic circulation and of the storm is not in the middle of this diameter, but is at some distance behind. As a further consequence, the gradients are steepest in the rear of the storm centre. 4. A consideration of the relations stated in the preceding show that a cyclonic circulation cannot be resolved into the translation of a rotating disc or mass of air. The fact that the main supply of the energy is applied in front of the cyclone suggests that it is perpetually renewed in front, and that, in fact, its motion and transmission are hence rather to be explained by some process analogous to the transmission of a wave. 5. The direction or line of advance of these storms appears to be mainly determined by the rainfall distribution. There is a very marked tendency for storms to form in and to run along the south-west monsoon trough of low pressure, if it be in existence at the time of the formation of the storm. 6. The lie of the south-west monsoon trough of low pressure at any time, and hence also of the most probable tracts of cyclonic storms at that time, depends upon the relative strengths and extension of the two currents. When both are blowing strongly, as is usually the case in July and August, the most probable direction of motion of a cyclonic storm at such a time is west with a slight curving to north, if the storm continues its course westwards after passing into the Central Provinces. If the Bombay current be weak, the storm will probably either break up in the Central Provinces or recurve rapidly to north.

Meteorologische Zeitschrift. Herausgegeben von Dr. J. Hann und Dr. W. Köppen. April to June 1891. 4to.

The principal articles are:—Die Hagelschläge des 21 August 1890 im Steiermark: von Prof. K. Prohaska (8 pp.). This is an account of the phenomena in Styria which accompanied the whirlwinds and hailstorms in France and North Italy which have already been noticed in this Journal. Prof. Prohaska gives an account of three storms with terrific hail which passed along the same tract between 5 and 7 p.m. on that day. The hail was of the size of goose eggs in some cases, and masses of stones were frozen together by regelation in court-yards to the depth of a metre, and you could hardly push a stick into them. The contour of the country had no influence on the track; it was determined by the isobars and went straight over mountain and valley. Its speed was greatest over flat country, so that mountains retarded it. Among the most interesting observations was that of the clouds; before each of the storms masses of cloud were sucked in towards the approaching storm, and moved with great rapidity. The thunder and lightning was very slight.—Die Luftdruckverhältnesse von Krakau nach den stündlichen Barographen-Aufzeichnungen (1858-1888): von Dr. R. B. Buszczynski (7 pp.).—Eine Beziehung zwischen dem Luftdruck und dem Stundenwinkel des Mondes: von R. Börnstein (10 pp.). This is an attempt to connect the barometer with the lunar day. Dr. Börnstein has taken the continuous records for several years for Vienna, Berlin, Hamburg, and Keitum in Sylt. He gives the following results: 1. The existence of an atmospheric tide is not traceable in the barometer records. 2. At Berlin, Hamburg, and Vienna, he finds a single oscillation of which the minimum occurs at moonrise. This is true also at Keitum, but there the curve shows complications which Dr. Börnstein is disposed to connect with the tidal phenomena of the sea, but says that he requires a much longer series of observations than the 10 years he has available to establish this relation.—Bemerkungen eines Statistikers über meteorologische Mittelzahlen: von K. Brämer (8 pp.). This is a note by a statistician on the best mode of interpolation to fill gaps in meteorological observations, particularly of the barometer, and it contains at the end some valuable remarks, probably by Dr. Hann, which are well worth a study.—Resultate der meteorologischen Beobachtungen auf dem Gipfel von Pike's Peak (Colorado) 4,308 metres (14,134 feet) nach Beobachtungen von November 1874 bis inclusive Juni 1888: von J. Hann (20 pp.). This is an analysis of Pickering's Publication in the *Annals* of the Harvard College Observatory published out of the Boyden Fund. Dr. Hann gives long extracts from the daily journals to show what the experiences of the observers were, and translates Mr. Abercromby's account of his visit. It is remarkable that mountain sickness attacked almost everyone, though elsewhere it does not prevail at the height of 14,000 feet.—Eduard Brückner: Klimaschwankungen seit 1,700, nebst Bemerkungen über die Klimaschwankungen der Diluvialzeit (9 pp.). There are two papers on the oscillation

of climate in the June number. The first is by Dr. Kremser, and is a summary of Prof. Brückner's book of which the title is given above. The second is by Prof. Brückner, and is a notice of Richter's Geschichte der Schwankungen der Alpengletscher, which appeared in the Journal of the Alpenverein for the present year (8 pp.). Brückner deals firstly with the oscillation of large lakes like the Caspian as far as he can get data, and then treats of rainfall since 1830. He finds a 35 year period, and also maintains that at the glacial epoch the mean temperature was not more than 8° F. or 10° F. lower than at present. Richter's independent inquiry deals with the glaciers. He finds also a mean oscillation of 35 years, and he maintains that all the stories of passes now closed by ice having been used in past ages, are not corroborated by any evidence now to be found.

Repertorium fur Meteorologie. Herausgegeben von der Kaiserlichen-Akademie der Wissenschaften. Band XIV. No. 9. 1891. 4to.

This contains a paper by Dr. Wild, entitled "Ueber den Einfluss der Aufstellung auf die Angaben der Thermometer zur Bestimmung der Lufttemperatur" (71 pp. and 2 plates). This is a contribution to a much discussed subject. Prof. Wild, however, has not on this occasion compared any of the modes of exposure employed in Western Europe. He has taken (1) his own screen composed of two concentric cylinders of zinc. 2. A screen, called by him the louvre screen, made of sheet brass and partially louvred. 3. A screen made of brass like No. 1, erected on north side of observatory. 4. A set of thermometers suspended on a post at different heights and separated from each other, and screened from the sun by sheet brass; this protection being rotated to suit the sun's position. As to instruments, he employed, in addition to ordinary thermometers, Hasler's metallic thermometer, Richard's thermograph, and Negretti and Zambra's turn-over thermometer; ventilation was applied in all cases where it was possible. The comparisons are set out in very great detail. The final conclusions are for annual means: 1. The louvre screen gave right results with and without ventilation. 2. The Wild screen gave without ventilation a mean 0°·1 centigrade too high. The brass screen on north side of house ventilated gave 0°·1 too low; the thermometers on the post gave means too low. A thermometer lying on the bare ground or on snow in winter gave a mean 1°·8 too high. These general results show considerable variation according to the season, and even greater when examined from the point of view of diurnal range, but for these details we must refer to the original paper.

Symons's Monthly Meteorological Magazine. April to June 1891. Nos. 303-305. 8vo.

The principal articles are:—The great snowstorm of March 1891 (7 pp.). The area visited seems to have been a belt about 120 miles wide, extending from about Cheltenham on the north to Jersey on the south, or say from Colchester on the north to Dieppe on the south, and reaching from the south of Ireland eastwards to Holland. The snow was much deeper in Cornwall and Devonshire than anywhere else.—The theory of halos and parhelia: by the Rev. A. K. Cherrill (12 pp.).—A changeable May (4 pp.).

Transactions of the Sanitary Institute. Vol. XI. 1890. 8vo. 352 pp. 1891.

This is principally a record of the Congress held at Brighton in August 1890. The meteorological papers were:—The climate of Brighton: by F. E. Sawyer (9 pp.). This is a summary of 21 years' observations, 1868-1888.—Teneriffe as a health resort: by G. W. Struttell (6 pp.).

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ON THE VERTICAL CIRCULATION OF THE ATMOSPHERE IN RELATION TO THE FORMATION OF STORMS.

By W. H. DINES, B.A., F.R.Met.Soc.

[Received January 3rd.—Read May 20th, 1891.]

It is doubtful whether a correct knowledge of the causes which originate and maintain a cyclonic disturbance would be of much practical importance in the way of enabling better forecasts to be made, but the subject is one of such great interest, and also it may be said of such complexity, that a discussion of the problem should be welcome.

There are certain facts relating to these storms which are well known, and with which any theory on the subject must agree; there are also certain well-established mechanical and physical laws, amongst which the principle of the conservation of energy stands first, without reference to which an inquiry into the causes of the phenomena is impossible.

It is admitted on all hands that the unequal heating of the surface of the earth by the sun's rays is the primary cause of all wind, but considerable uncertainty prevails as to the exact method by which the final result is brought about.

At first sight it appears strange that the warmest strata of the air should be those lying nearest to the earth's surface; with sea water the exact opposite holds, the coldest water being at the bottom of the great oceans, and the warmest at the surface. Equilibrium is impossible with a layer of warm water lying below a layer of cold, and the same is true of air provided the two layers be at the same pressure. In the atmosphere the air is compressed by the superincumbent mass, and as we ascend the pressure becomes less, the change at sea-level being about one-tenth of an inch of mercury for every 90 ft. When the air becomes subject to a decrease of pressure it expands and at the same time becomes cooler, and the amount of cooling which will occur from this cause when dry air is raised 90 ft. above sea-level is about $0^\circ\cdot5$.

It is strange that a fact so well known should be often ignored, but since it is so, it may be well to point out that this cooling does really occur. The common experiment showing the condensation which occurs in the receiver of an air pump may be cited. In this case the air rapidly assumes the temperature of the walls of the receiver, and the cloud disappears almost as soon as it is formed. If another proof be required it may be found in a study of the method of obtaining the low temperature by which meat is carried through the tropics, the storage rooms being kept considerably below the freezing point by the expansion and consequent cooling of air. This principle is of great importance in meteorology, for it is due to it that the air in contact with the earth is generally warmer than the air above. The question whether air will ascend depends not upon whether it is warmer than the air above it, but upon whether it is so much warmer that after its ascent, expansion, and cooling, it will then be warmer than the air at its new level.[1]

Under ordinary circumstances this ascent of warm air will not occur, for dry air when raised in height generally becomes cooler than the surrounding atmosphere, and conversely dry air in descending generally becomes warmer.

It is not necessary that the change of pressure should be produced by a change of altitude; change of locality from a position of high to a position of low barometrical pressure will have the same cooling or warming effect, hence, unless other circumstances of more importance interfered, a higher temperature would always be found to accompany anticyclonic conditions of weather.

The rate of cooling given above refers only to dry air; it must also be remembered that although expanding air is invariably cooled in virtue of its expansion, yet it may happen that it is at the same time receiving heat from some external source, by passing over warm land or sea for example, so that the final result may be an increase of temperature.

When air containing vapour expands and cools, the change of temperature follows practically the same rule as that which applies to dry air until condensation occurs. As soon, however, as a cloud is formed, the latent heat set free by the condensation checks the cooling process, and the decrease of temperature proceeds much more slowly; and thus it happens that the change of tempera-

[1] *Deschanel's Natural Philosophy*, Part II. p. 502.

ture in a vertical direction is often such that moist air after ascending, cooling, and condensing some of its vapour, is still warmer than the surrounding air at its own level. Under these circumstances an upward convection current is formed, and according to the theory which has been so ably brought forward by Prof. Ferrel, this is the chief cause of a cyclone.

Turning now to the storms themselves, it is well known (1) that they do not occur on the Equator; (2) that, speaking roughly, the winds blow in circles round the central barometrical depression; (3) that there is a decided indraft of air towards the centre, the wind directions being more or less inclined to the isobars; (4) that the central parts are generally characterised by clouds and rain.

Without entering into any strict calculation it is easy to see that, whatever the cause of the storm, the centrifugal force due to the circular motion must be accompanied by a decrease of pressure at the centre. It follows also from (3) that there must be a decided upward motion of the air somewhere in the central parts, for if this upward current is denied it is impossible to say what becomes of the air which is continually moving towards the centre. It cannot become annihilated, neither can it sink into the ground, it must therefore ascend and flow out above.

It will be well now to trace as far as possible the changes of temperature which accompany the vertical circulation.

In rising in the central parts the change is probably adiabatic, for there is nothing in contact with the air to which it can give, or from which it can receive heat. It can hardly lose heat by radiation, or receive it by the direct action of the sun's rays, for, as a rule, the ascending current is covered by a dense layer of clouds. Dr. Hann thinks that the air is cooled by the cold rain or snow falling from a higher level, but it appears to me that this is only partly the case. Raindrops descend with a nearly uniform velocity, which never reaches a very high value, even with the largest drops, and it is known that if the velocity of a drop is not increased it is warmed 1° by friction with the air for every 772 ft. that it falls, or if not warmed it imparts an equivalent amount of heat to the air. My father made many observations on the temperature of rain, and found it invariably above that of the wet bulb, and generally above the temperature of the dry bulb thermometer. The falling drops must, however, to some extent impede the upward flow of the air. The adiabatic rate of cooling depends on the amount of moisture and the temperature. Tables have been drawn up by Dr. Hann and translated by Prof. Abbe (*Smithsonian Report 1877*) showing the amount under various conditions. Without entering into details, it is sufficient to remark that the air in ascending is cooled through a considerable range of temperature, but that, owing to the latent heat set free by the condensation which forms the clouds and rain, it is not cooled so much as dry air would be in rising to the same height.

There is reason to think that the air in its passage as an upper current to anticyclonic regions is considerably cooled by radiation into space. It carries with it a certain amount of water in the form of ice crystals, which we see as cirrus cloud. Pure snow is but very little affected by the sun's rays, the heat being reflected, but it is a very good radiator, and therefore it is probable

that the cirrus cloud, and through it the air in which it floats, is cooled by radiation to a greater extent than it is warmed by the sun.

In descending from the higher level the air is doubtless warmed by the increase of pressure. If the change of temperature be purely adiabatic, the rise of temperature will exceed in amount the fall which occurred in the ascent; for in this case there is no water to be evaporated, and thus use up the heat, the equivalent of which was given out by condensation in the ascending current. It seems probable that the change is adiabatic, for air is a bad radiator, and dry air allows the sun's rays to pass without absorbing much heat. There are, however, two points to be remembered; since the region of the descending current is anticyclonic, there is no upper cloud covering to prevent radiation; and also the current probably occupies a much larger space than it did in ascending, hence it has a smaller velocity and more time is allowed for radiation to take effect.

In passing near the earth's surface from a region of high pressure towards the centre of a storm, the air does not travel in a straight line; it therefore comes in contact with a large extent of surface, throughout different parts of which widely different temperature conditions prevail. Hence it is impossible to say what change of temperature will occur by contact with the earth's surface, but it may safely be asserted that this contact will be the predominant factor in the determination of the final temperature. Two points also are clear, the air will be cooled in virtue of the decrease of pressure to which it is subjected in approaching the centre, and also in its passage it will receive a large amount of moisture and reach the centre as a damp wind: this will be the case particularly where the course has been over the sea or wet ground.

The above rough outline of the circulation has been given without reference to the causes which produce it, or to the various influences which often largely modify the result; it is, however, I think fairly applicable to the average case.

Two theories have been suggested to account for the phenomena of storms. One, the convectional theory, is that the central air rises in consequence of its greater relative warmth, this warmth being produced by the latent heat set free by condensation. It must be remembered that an absolutely higher temperature in the centre is not required, but only such a temperature that, after the adiabatic heating produced by a change of position without change of level to regions of higher barometrical pressure the air, may then be warmer than the strata lying at its own level. Thus, if the depression of the mercury in the centre be one inch, this difference of pressure will account for a difference of 5° of temperature, and thus air in the centre will rise, unless it be more than 5° below the temperature of the air outside the depression at its own level.

It can be shown that if from any cause an upward current be established, the air rushing in to supply its place will receive, in consequence of the rotation of the earth (unless the locality be close to the equator), the eddying circular motion characteristic of a cyclone,[1] so that the convectional theory whether true or not, is capable of producing the effect.

[1] *Routh's Rigid Dynamics*, Chap V. p. 264 and f.

The other theory is that the storms are circular eddies produced by the general motion of the atmosphere as a whole, just as small water eddies are formed in a flowing stream of water. If an eddy of this kind were produced in the upper air it would, owing to the centrifugal force, lessen the air pressure at the centre, the air below would rise, and the eddying motion would soon extend to the earth's surface.

It appears to me that the convectional theory is the most probable, for according to it a copious supply of moisture is required to maintain the energy of a storm, and it has often been noticed that these storms follow the course of the Gulf Stream, where the moisture is supplied by the warm sea water. A short study too of the secondary disturbances which often appear in winter will show that they exhibit a decided preference for the sea, often travelling up the English Channel or down the North Sea, in preference to passing over the land. This theory also explains the permanency of wet or dry weather when once thoroughly established, for dry weather having once set in, the moisture required to maintain a cyclonic disturbance is absent, and conversely the place where the air and ground are damp from previous rain is the place over which a storm is most likely to travel.

The other theory will equally well explain the formation of rain at the centre, produced by the dynamic cooling of the ascending current ; it is also easy to suppose that the storm would be most violent over the sea where the surface wind is least impeded by friction, but it seems to me that to prove it to be the true theory it is necessary to show that storms are most numerous on the lee side of mountain ranges, that is to say on the western side in the tropics, and the eastern in temperate latitudes. Eddies in a stream are most frequent where the even flow of the water is disturbed by irregularities in the sides or bottom, and apparently the same rule ought to hold for air.

Unfortunately, we have very little information about the temperature of the upper air. Mountain observatories throw some light on it, but of course they cannot exist over the sea, where the results would be especially interesting. Again, it is a question whether the temperature observed on a mountain is identical with the average air temperature at the same level. Probably the two temperatures would agree in windy weather, but it is doubtful whether they would do so in a calm. A knowledge of these temperatures would afford a direct proof or refutation of the convectional theory, but it is difficult to see how this knowledge can be obtained.

DISCUSSION.

Mr. GASTER said that it was very difficult to follow this paper, as it was one which required very careful consideration, and could not be adequately discussed after hearing it merely read through once. He took exception to the statement that temperature in an anticyclone is higher than in a cyclone. In the winter months, at all events, the condition is exactly the reverse, and he should wish for statistical evidence before accepting the statement as it stood. The determination of the true temperature of the air in cyclones and anticyclones is surrounded with difficulties. With an anticyclone there is, as a rule, little cloud, and the radia-

tion of heat from the earth's surface at night and in winter is then very large; the question which arises is, therefore, how much of the cold observed under such circumstances is due to radiation, and how much to the downrush of air. A cyclone is accompanied with a very cloudy sky and often rain, so that there is little radiation. He had an idea that a series of good simultaneous temperature observations taken at sea, where the effect of radiation both terrestrial and solar is exceedingly small, would greatly assist in solving the question whether the low temperature in the centre of an anticyclone is due to the downrush of cold air from higher regions, or to the effect of radiation.

Capt. Wilson-Barker said that he agreed, to a certain extent, with Mr. Gaster's remarks concerning the relative temperature of cyclones and anticyclones. He thought that Dr. Hann had gone too far in the conclusions he had drawn from the results of observations made at mountain observatories, for he (Capt. Wilson-Barker) believed that such observations might at times be very misleading in studying the question of the vertical circulation of the atmosphere. Observations taken at sea would be of great value; and now that captive balloons were being used by ships, he thought we might hope for some light to be thrown on the subject of the vertical circulation in the atmosphere, in a manner which could never be attained by observations over the land. He was glad to see that Mr. Dines had taken up the subject.

Mr. Bruce said that balloons could undoubtedly be of great service in investigating atmospheric conditions at various elevations above the earth's surface; and for such a purpose it would not be necessary to use large balloons, such as would carry persons, but small balloons of sufficient capacity to carry a few instruments would be all that need be used.

Inspector-General Lawson drew attention to Col. Reid's description of the great hurricane which occurred at Barbadoes on August 10, 1831, and described the circulation of the air as indicated by the wind changes experienced at the various places which came under the influence of this hurricane. This commenced in the immediate vicinity of Barbadoes: in the evening its centre passed over that island, and travelled between St. Vincent and St. Lucia. During this course the winds which occurred were mainly from the North-east, then, after a short lull, from North-west, and after another lull, from the South-west, the first and last being aerial currents seen almost every day at Barbadoes, and that from the North-west between the other two, and visible occasionally only. All the changes occurred at Barbadoes; at St. Lucia the North-easterly gale was met with at the north end of the island, at its south end this was followed by a South-westerly one; and at St. Vincent the hurricane commenced at North-west, and shifted to South-west, then backing to the South-east gradually ceased. At Barbadoes, during the violence of the gale, the wind backed about eight points each shift; at St. Vincent a similar quantity, but at St. Lucia sixteen; but nowhere was there a gradual shift, as it is usually supposed to do in a circular storm.

Mr. C. Harding said that he was very glad that Mr. Dines was working on the same lines as Prof. Ferrel, in America, as a worker at home in this direction was much needed. He did not think Mr. Gaster's idea of organising air temperature observations over the sea was at all necessary, for if provided with the temperature of the sea, he could give a very close approximation to the temperature of the air immediately above it. Mr. Gaster had said that the sky was clear when anticyclonic conditions prevailed, but during December last, when the weather in the British Islands was under the influence of a large anticyclonic area, the sky was completely overcast during nearly the whole of the month. He heartily believed in balloon observations, and only wished that somebody would work up all the observations which had already been made, especially those of Mr. Glaisher. It was often found by balloonists that the changes in the temperature of the various strata of air passed through were very irregular. Mr. Glaisher had found that when an ascent was made in the evening the air temperature increased for some considerable distance from the earth's surface instead of decreasing. He (Mr. Harding) was firmly persuaded that it was imperative that meteorologists should thoroughly study the laws which governed the movements of cyclones and anticyclones.

The President (Mr. Latham) said that he did not believe much in the convection of air. He had been told when making some experiments on underground temperature, for which purpose long tubes sunk in the ground were used

that he would have to make some allowance for the convection of air in these tubes, but he had not found it necessary to apply any correction whatever to the observations, which extended over a number of years.

Mr. GASTER remarked that he had understood Mr. Dines to say that the air travelled three or four times round the central area of a cyclone. He had never observed such an occurrence, and should much like to have such a case pointed out to him.

ON BROCKEN SPECTRES IN A LONDON FOG.

By A. W. CLAYDEN, M.A., F.R.Met.Soc.

[Received March 18th.—Read May 20th 1891.]

In October 1887 a paper[1] was read before the Royal Meteorological Society by Mr. Henry Sharpe upon *Brocken Spectres and the Bows which sometimes accompany them*. This interesting communication contained a large number of descriptions of the somewhat rare phenomenon, and from them the author drew certain conclusions.

Some points, however, he left without any attempt at explanation, notably the dark rays occasionally seen in prolongation of the arms of a "spectre," or in some other way connected with it.

Moreover, although he showed reasons for believing that the assignment of enlarged size to the shadow was due to an error of judgment in estimating its distance, he offered no suggestion as to the reason for an error of very frequent occurrence.

These two points I have often thought over, until I was led to the formation of a theory by which they seemed explicable. Several times have I begun to commit my ideas to writing, but only to abandon the attempt in the hope of obtaining some experimental evidence to lend them support.

With this object in view I have repeatedly tried to raise my own "spectre," but for a long time with indifferent success.

Frequently I have fancied I could just make out my shadow on a fog at night by the light of a gas lamp. Three times also I have dimly seen a similar appearance by standing on the roof of my house when a fog was clearing, so that it still lay thick upon the ground while the sun was shining with a feeble lustre around me. None of these shadows, however, were clear enough for my purpose. I was conscious of their presence, but could see no definite details.

On the night of February 17th, 1891, I was looking at such a faint shadow thrown by the light from a railway-carriage lamp, and it struck me that in

[1] *Quarterly Journal.* Vol. XIII. p. 245.

order to see it plainly all that was wanted was a brighter light and protection from cross-lights.

The Saturday following there was fog, so I went out into my garden and got my brother, Mr. C. E. Clayden, to burn some plaited strands of magnesium ribbon a few feet behind me. Instantly there stood the long-sought "spectre." Its head was sharply defined, its body fairly so, but the brim of its hat was prolonged into long shadowy horns growing fainter and broader towards their tips. Its arms could only be seen as indistinct masses of shadow when they were moved. There was a slight accession of light near the head, but no coloured glories and no bow.

The diagram (Fig. 1) gives a fair idea of what I saw.

Having found that the phenomenon could be produced, I substituted a steady lime-light for the sputtering magnesium and then called out my household to come and say what they saw. Each gave much the same description.

FIG. 1.

No one could see the shadow of any other, and if two of us stood close together our shadows merged into one. Thus, when my wife stood close to my right side, the left-hand margin of my spectre was unchanged, but on the right it simply faded away in broad masses of light and shade.

I made several attempts to photograph the appearances, fixing the camera close in front of myself so that the lens should lie as nearly as possible in the same position as my eye. None of these plates were sufficiently exposed, and the fog cleared before I could try again.

Monday the 23rd brought a denser mist, so I determined to make the camera photograph its own "spectre," placing a hat on top of the apparatus

to show the dark rays in continuation of its brim. Exposures of 10 and 15 minutes gave satisfactory results, and I am glad to be able to show prints from the negatives.

Whilst the photographs were in progress I made some measurements of my shadow. The head, about level with the ears, subtended the same angle as 2 ins. at a distance of 12. A faint white bow visible on this occasion had an angular radius of 45° to its inner margin and 52° to its outer edge. No trace of colour could be detected.

I noticed that the fog particles were so large, that within a foot of the light, where they were illuminated with great brilliancy, the individual droplets were plainly visible. The fog was very wet, everything being saturated with moisture, and the temperature about 39°.

I found that if I breathed heavily, so that the condensed vapour drifted across the shadow, fragments of circular glories appeared fringing the head of a larger shadow than that on the fog. Indeed, I could see the fog shadow through the one cast on my breath. In a similar way, when I poured some hot water over a broom and waved it at arm's length on the windward side of the shadow, the veil of dense mist which drifted from it gave a shadow intermediate in size but no glories.

One more observation was made, namely that if I stood about 8 or 10 ft. from the light the outlines of the shadow were very distinct, but they became less so as I moved away, until at a distance of about 20 ft. not a vestige of shadow could be seen. All parts of the fog seemed about equally illuminated by the irregular reflection of light from the particles nearer to the light.

When I measured the angular width of my spectre I asked the others to say how far away their shadows seemed to be. After a little hesitation all agreed that they seemed to be "about half across the garden," that is about 25 or 20 ft. The size was gigantic enough, but then the light was radiated almost from a point. My own estimate was fully in accordance with the above, but I felt that it was quite impossible to feel any confidence in the judgment of the distance of such an intangible and rather vaguely defined object.

When the mist became thinner, the spectre seemed to retire, and its angular width became less. The dark rays were always present.

The observations suggest three questions:—

Did we estimate the distance of the shadow correctly? If not, how were we led astray? What were the dark rays?

Now there are two ways of getting an answer to the first question—from the angular measurement of my shadow, and from the photographic image.

First take my shadow.

The semi-diameter of the head subtended an angle equal to 1 in. at a distance of 12. This is an angle of about $4\frac{3}{4}$°.

The corresponding half-width of my head to the outer margin of the ears is about $3\frac{1}{2}$ ins., and the light was about 100 ins. behind. Hence the angle between the line from the light to the centre of my head and the ray which just grazed my ear must have been about 2°.

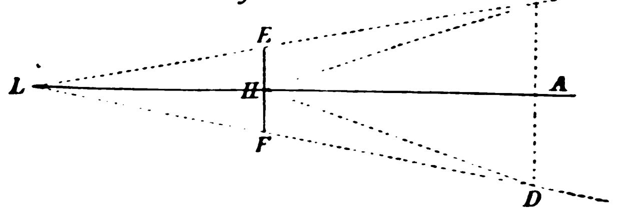
Thus if L (Fig. 2) is the light and EHF my head, the angle ELH is 2°,

Also if H represents my eye, and the angle DHS the angular width of the shadow, the angle AHS is 4¾°. Hence LE and HS will meet at some point, which must be the actual edge of the "spectre."

Now we have a triangle SLH, the angles of which are known, and the relative length of the sides can be calculated, so giving the distance HA. This comes out about 6 ft.

Now take the photograph.

Fig. 2



Here the data are:—focus of lens 5½ ins.; width of hat 9¾ ins.; width of corresponding image 1½ ins.; distance of light 70 ins. From these figures the semi-diameter of the hat subtended an angle at the light of about 3¾°, while the semi-diameter of the shadow gave an angle at the lens of 7¾°. A computation similar to that above given again gave a distance of about 6 ft.

Of course all measurements of the angular diameter of the shadow or its image can only be approximately correct, but this fact makes it all the more remarkable that the two results should be practically the same.

Moreover, their correctness is checked in other ways. One photograph shows the shadow partly projected on a paling, partly on the fog. It is obvious that the latter portion is larger than the former. Hence it is nearer. The paling was about 8 or 9 ft. away. Again the shadow on my breath was within a foot or so of my eye, the shadow on the steam from the hot water must have been 3 or 4 ft. away, and this last was intermediate in size between the breath shadow and the fog shadow.

It therefore seems to be proved that the "spectres" were only about one quarter of their apparent distance from us.

This leads us to the second question: Why were we mistaken? But in order to answer it, and at the same time arrive at the explanation of the dark rays, perhaps it will be best to state certain postulates which I think no one will question.

1. The brighter the illumination of a fog particle the larger it will look in consequence of irradiation; 2. The nearer a given particle is to the source of light or to the edge of a cloud, the brighter will be its illumination; 3. At a short distance from the source of light (or edge of the cloud) the particles are mainly illuminated by irregular reflection from particles which lie nearer. The result is that an object can then cast no distinct shadow even upon an opaque screen only a few feet distant. This point is reached long before the source of light ceases to be visible, as may easily be observed any time when

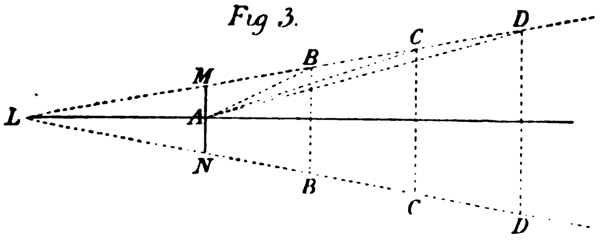
the sun is gradually dissipating a morning fog, when it can be seen, and may even be quite dazzling to the eyes, before the body can cast a distinct shadow.

It follows from the first two statements that if a man is surrounded by fog he will be able to see only a short distance into it where the particles are brightly illuminated, but where they are shaded by his body his eye will be able to penetrate much further. Everyone must have noticed how thin a veil of brightly illuminated mist is enough to completely hide objects beyond.

When a man, therefore, looks at his shadow on a fog he is practically looking down a hole in that fog. The walls of this hole are made of bright and therefore opaque fog, while the hole itself, so to say, is filled with a mist which is comparatively transparent.

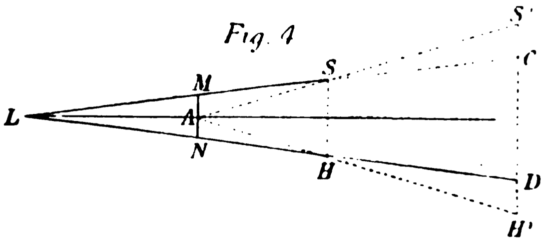
Thus if L (Fig. 3) is the light, and MN the man's head, its shadow will be marked out by the lines BCD. At B the difference of illumination will be great; at C the light outside the shadow will be fainter, and a larger proportion will be due to irregular reflection. At some distance DD, where the direct light can no longer cast a shadow, all parts of the fog will be equally illuminated, and the shadow cone will come to an end.

Fig 3.



Moreover, as the observer looks down the shadow, its boundary will be bright at B, less bright at C, and at D the tint of the shadow wall will match that of the shadow itself. Clearly this point DD must determine the true position of the "spectre."

Fig. 4



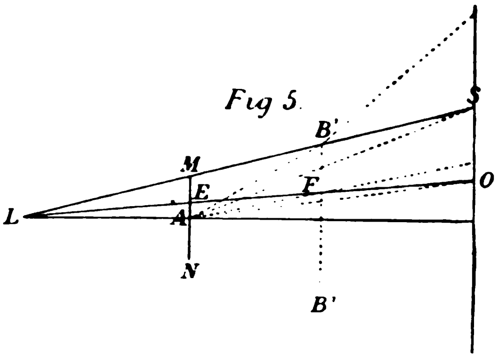
But when asked to estimate the size of the shadow he will instinctively attempt to gauge its distance, and in order to do so he will not look at the opaque illuminated fog but rather at the shadow itself where the mist is comparatively transparent. Hence it will be referred to a greater distance, with the result that its apparent size S'H' (Fig. 4) will be too great.

The dark rays are simple enough. They are the gradually darkening

walls of the shadow. All parts of the spectre are really shaded off in this way, but where the true shadow covers only a small angle this shaded margin is so small as to be hardly noticed. Where, on the other hand, the width is greater, the shading will cover a wider angle.

Thus if A (Fig. 5) is the eye and AE a narrow part of the man, and if BB marks the distance at which the darkening of the mist becomes visible, and SO the position of the shadow, then the angle FAO will give the apparent

Fig 5.



width of the shaded margin. Similarly, if MA is a wider part of the man its shaded margin will cover the angle BAS. These shaded margins are then unconsciously projected on the plane of SO. The darkest part of the ray matches the tint of the shadow and has the same dimensions, but the fainter parts of the ray shade off imperceptibly into the luminous mist, and since they are nearer to the eye they cover a wider angle and so look wider. The spreading out, in other words, is merely an effect of perspective.

It seems also that the presence of the shaded fog within the shadow may affect the tint of the shadow and its luminous walls. In one sense the shaded particles will reflect some light from outside the shadow, so lightening its tint, while, on the other hand, they will tend to obliterate some of the light which might reach the eye from particles outside the shadow. But whichever effect were the stronger, the explanation of the appearances seen would not be affected.

A reference to the figures will show that very little modification is necessary to make them equally applicable to what may be called natural Brocken Spectres, the dark rays seen by Mr. Abercromby and others, and the shadowy arms often seen, being obviously similar to the appearances we noticed. The over estimate of a "spectre's" size will be similarly explained, and the inability of one person to see another's spectre is a consequence of the fact that the observer looks through a wall of illuminated mist several feet in thickness, into its dark interior.

If a person is in a fog, he must be close to its margin or the light will not throw a shadow. If he is on its margin he will see the phenomena to the best advantage. If he is outside it, but not too far away for the details of

his shadow to be sharp, he may be able to see down the shadows of others, but will not be able to see much of the dark rays. Again, when he is in or upon the margin of the mist his shadow will appear enlarged, and its apparent size will depend upon the density of the mist and the brightness of the light. If, on the other hand, the air is clear for several yards between him and the mist, the shadow ought not to seem larger than life size unless he is really looking through a thin wreath of bright mist at a shaded and much more distant background.

I have carefully studied the instances quoted by Mr. Sharpe. Some are couched in language which is evidently designed with a view to picturesque effect rather than accurate description, but if allowance is made for this, and if also it is borne in mind that the shadow of a man cannot possibly be sharp at a distance of a mile or more, it will be seen that the conclusions I have drawn are supported by fact. I also append a letter from Mr. J. E. Walker.[1]" of the Friends' School at Saffron Walden. He has twice witnessed the phenomenon. On one occasion he was in the fog, and his spectre seemed 1¼ times life size, but on the other he was in clear air and the cloud some distance away (he gives the distance as about one mile, which is probably too great), and in this case the shadow was about life size.

I have not entered upon the questions of bows and glories because my ex-

[1] "SPECTRES" IN THE ENGLISH LAKE DISTRICT.—Three gentlemen and myself witnessed this phenomenon on Blakefell on a July evening in 1873, under the following conditions:—

The summit of the mountain is about 2,000 ft. above sea-level, and no high hills obstruct the view between it and the Irish Sea to the west. In front lies a deep boggy valley. We had reached the top shortly after 8 p.m., and were soon interested in watching the formation of a white cloud in the boggy valley beneath. Slowly the bank moved round to the left until it reached a position behind ours at a distance of about one mile, and had very much the appearance of ordinary cumulus. As the sun neared the horizon our shadows became very clearly defined on the cloud. A hat thrown up was distinctly seen. In ten minutes the sun set and the spectres vanished.

Conditions, &c.

Place : Blakefell, Cumberland.

Time : At sunset in July.

Atmosphere : Clear, the day had been a hot one.

Size : Apparently not enlarged.

Position of Sun: Below us, so that the shadows were somewhat higher than the mountain.

Distance of Spectres : About 1 mile.

On another occasion, I cannot recall the year, I was passing over Low Fell, which lies between Loweswater Lake and Lorton Valley, at Christmas. The valleys were filled with dense fog, the top of Low Fell, 1,400 ft., being just clear. With a scanty amount of visible vapour between me and the sun, my shadow was thrown upon the more dense fog beyond, and appeared to be increased in size to about 1¼ times at a distance of 20 yds. It was of a very vapoury semi-transparent character, varying with the density or whiteness of the mist. The shadow was surrounded by a fog-bow, not showing prismatic colours, which formed an arch over the figure and then converged to my feet. These phenomena accompanied me for half an hour and for nearly a mile as I crossed the hill.

Conditions, &c.

Place : Low Fell.

Time : 10 a.m., mid-winter.

Atmosphere : Fogs of varying intensity, moving to and fro, with a clear grey blue above. Not frosty.

Size: Apparently 1¼ times larger than myself.

Position of Sun : About level with the top of the mountain.

JNO. E. WALKER.

periments were not satisfactory enough. Perhaps some other night the fog may be in a different condition and I may be able to study these also, but I am inclined to think that the lime-light is not brilliant enough to show coloured bands on an ordinary fog. Perhaps some one who has the command of a powerful electric light will put this matter to the test.

So far, however, as the shadows themselves are concerned it will now be easy for anyone to conjure up his own spectre, to be studied at leisure free from the glamour of magnificent surroundings.

DISCUSSION.

Mr. Sharpe said that he was gratified to find that Mr. Clayden had proved that the suggestion which he (Mr. Sharpe) had made in his paper on "Brocken Spectres," that the gigantic size was due to an error in judging distance, was correct. He could not quite agree with Mr. Clayden's explanation of the dark rays.

Mr. Whipple said that when returning home from the Kew Observatory, on foggy nights, he sometimes carried a lighted taper to guide him across the Old Deer Park. It was necessary to hold this somewhat behind him, and he had often seen his spectre projected on the fog. In fact, he had so frequently observed it that he had never regarded it as a noteworthy phenomenon. The shadow usually appeared to be about half as big again as himself.

Mr. Inwards remarked that there was a notable instance of error in judging the distance of the spectre in the letter from Mr. Walker, who estimated the distance of the shadow as one mile, but at the same time said he saw the shadow of his hat when he threw it up in the air.

Mr. Southall said that he once saw his spectre at the top of Snowdon, about a quarter of an hour before sunset: the shadow appeared to be very gigantic. Deception as to distance was very common on high mountains.

Mr. Symons said that Mr. Clayden appeared to have proved that the large sizes reported were due to error in judging distance, but the phenomena of the "glories" which were sometimes seen still required to be accounted for.

Mr. Clayden, in reply, said that he had every reason to believe that his explanation of the dark rays was the true one. As Mr. Inwards had pointed out, Mr. Walker's statement was a notable instance of exaggeration in judging distance.

AN ACCOUNT OF THE "LESTE," OR HOT WIND OF MADEIRA.

By H. Coupland Taylor, M.D., F.R Met.Soc.

[Received March 16th.—Read May 20th, 1891.]

I had intended bringing before this Society, with their permission, a sketch of the climate of Madeira, but finding it would necessarily extend to too great a length; I am confining my present remarks to one of the most interesting phases of that climate, namely, to an account of the "Leste," or hot wind which is occasionally experienced in that island.

Being an invalid, I must beg for the indulgence of the Society for irregular times of observation and other defects the Fellows may discover in the following paper.

I must first state that my instruments are placed in a regulation Stevenson screen, and the blackened bulb *in vacuo* thermometer upon a post about 4 ft. from the ground. The maximum and minimum thermometers are by Casella, and duly tested at Kew, while the hygrometer (Mason's dry and wet bulbs) is by Negretti and Zambra. I also have had in use for some months a self-registering hair hygrometer by MM. Richard Frères of Paris, as likewise a thermograph by the same makers; but no very severe Leste has occurred since I had them.

This "Leste" is a very dry and parching wind and sometimes very hot, blowing over the island from the East-north-east or East-south-east, and corresponds to the Sirocco of Algeria or the hot North winds from the deserts of the interior experienced in Southern Australia, and locally known as "Brick-fielders." It has been likened also to what is known in Italy and Sicily as the Sirocco, but notwithstanding that both winds have the same origin they differ materially; for this latter having become saturated with moisture in its passage over the Mediterranean, is, as a rule, damp and enervating, a great contrast to the Leste of Madeira, which, as I have before mentioned, is very dry. Occurring in such an equable climate, both as regards temperature and humidity, as that of Madeira, it possesses some special features of interest and no doubt attracts there a more general attention than it would do in some other more variable and extreme climates.

Its general characteristics were thus described by Dr. Heineken, who took careful observations in Madeira over 60 years ago, from the years 1826-1831, and the description fairly depicts its general character. He says:—"It reaches us immediately from the coast of Africa, after passing over 300 miles of sea; not a cloud is to be seen during its continuance, the whole atmosphere is of one uniform unvaried blue" (a rare occurrence in Madeira) "of a peculiar character, as though viewed through what a painter would term a thin warm aerial haze. It blows from the east and south-east, lasts almost invariably three days, and encounters you like the puffs from the mouth of an oven or furnace. . . . Birds and insects seem to suffer from it more or less,

. . . Furniture warps and cracks, books gape as they do when exposed to fire, and it is generally inconvenient and oppressive."

Mr. Yate Johnson, in his *Handbook to Madeira*, in the excellent chapter on its climate, adds :—" It usually begins as a gentle warm breath, afterwards there is more motion and sometimes the wind increases to a strong breeze. . . . A thin haze extends over the land and gradually thickens out at sea until the horizon is completely hidden, and in that direction a low bank of grey cloud is seen in the east and south. In the earlier stages the Desertas are dimly perceived backed by a white cloud, but afterwards they become invisible." (The Desertas are a small group of islands only 10 or 12 miles distant.)

The special characteristics of this wind may now be described in more detail :—

It doubtless originates on the heated deserts of the Sahara, and is strictly analogous to the Sirocco of Algeria. As the air becomes heated it rises there in whirlwinds, carrying with it quantities of sand and dust to be borne along for hundreds of miles out to sea above the cooler North-east Trade current. It then gradually descends far out in the Atlantic, where it is experienced as a hot, dry, and often boisterous wind in Madeira and the Canary Islands, where it is called the "Levante." The reason why it does not become moist and enervating like the Sirocco of Palermo and parts of Italy by passing over the intervening sea is, I presume, due to its travelling at a much higher altitude in the former case, and thus it does not come into contact with the sea till it reaches the longitude of Madeira or thereabouts. But this wind is, no doubt, frequently modified before reaching Madeira, and so it may be asked what constitutes a Leste? and it is not always so easy to determine, as the indications of the slighter ones are not very pronounced, though those of a severe Leste are distinct enough. My opinion would be that there should be at least a difference of from 9° to 10°F. between the dry and wet bulbs, and this not merely at midday but at the morning and evening readings, and that this should be accompanied by a distinct rise in the temperature. Such a degree of dryness as these readings would indicate is never experienced in Madeira except when an Easterly wind is blowing.

Its occurrence is quite uncertain. Many months may elapse without its occurring, whilst, on the other hand, two or three of greater or lesser intensity may be felt within the course of a few weeks during the summer months. It is most frequent during the months of July, August, and September ; it occasionally also visits the Island in various other months, but being modified by the cooler temperature prevailing, instead of being intensified by the heat of summer, it passes by almost unnoticed by the public. If, however, the weather at such times is carefully watched, the sudden accession of a greater degree of dryness and warmth is clearly due to this cause. For example, on February 19th and 20th, 1889, the maximum suddenly rose from 64° on February 18th to 76° on the 19th, and the minimum from 53° to 66°·5, the significance of which is unmistakable when it is remembered that the extreme minima for a week together frequently do not vary more

than 2°. Again, on looking at the relative humidity we find the indications equally plain, for on the 18th the relative humidity was 74°/₀ in the morning and 77°/₀ in the evening, whereas on the following day it had fallen to 42°/₀ and 37°/₀ respectively!

The duration of the Leste is generally stated to be three days, but it may last only one day, and, on the other hand, it may last up to six or seven; or, after lasting perhaps a day or two, it may seemingly disappear entirely for one day, only to recur on the day following, *e.g.* July 19th to 21st, 1890.

It is generally believed that the Leste is felt more severely at high elevations in the Island than in localities nearer the level of the sea, but this has been questioned; on the whole, however, the evidence seems to establish the popular belief, although simultaneous observations have not been taken to a sufficient extent to absolutely prove it. But there seems no doubt of the fact that the climate on the hills is affected first, *i.e.* before that on the lower levels. For instance, on June 6th, 1890, a Leste was reported from Camacha (2,300 ft.) which was not felt in Funchal till the following day. Again, in a Leste noted by Dr. Langerhaus in September 1888, the minimum on the first day at an elevation of 1,200 ft. was 68°·5, whereas it was only 61° in Funchal. On July 10th, 1890, a Leste which was scarcely noticed at all in Funchal occurred at Camacha, when I registered a difference of more than 20° between the dry and wet bulbs, indicating a relative humidity of only 28°/₀.

The force of this wind is often considerable, causing a rough sea with crested waves, and attaining a force of from 4 to 5 or even 6, on Beaufort's scale. During its onset it gradually supersedes, while during its subsidence it is again gradually superseded by, the North-east Trade wind, which is generally blowing steadily over the Island of Madeira during the season of the year when the Leste most frequently occurs.

As far as my observations go the barometer shows no certain or decided movement. As a rule it rises slightly at the commencement, though that is not invariably the case. The fall after the termination of the Leste is much more regular and decided than any rise that may have taken place at its onset.

The sky is perfectly cloudless except for a low and ill-defined bank of cloud to the east and south-east horizon.[1] There is, however, a decided haze both over land and sea as seen near sea level, which gradually obliterates the horizon and renders the Desertas invisible, though they are only about 10 miles distant and rise to the considerable elevation of 1,600 ft. This very marked haze, with such a dry wind and cloudless sky, is one of the most interesting features connected with the Leste, and many explanations of it have been offered. The usual one adopted has been that it is due to the particles of dust from the Sahara floating in the upper regions of the atmosphere; indeed, dust has

[1] A peculiar oval-shaped cloud to which Prof. Piazzi Smith has called particular attention is sometimes seen from Funchal at these times, and is said to indicate a Leste blowing at a high elevation.

been deposited during violent Lestes in sufficient quantities to be collected by hand, but this very rarely happens. That there is at these times an abnormal quantity of dust in the atmosphere, even though it is quite impalpable, might be also inferred from the strictly analogous winds experienced near the Cape Verde Islands, where the amount of dust in the atmosphere causes what is known as the Red Fogs of those regions. Nevertheless, it is sometimes stated that the air during a Leste is "particularly free from dust." This statement may be so far true that there does not, as a rule, seem sufficient dust *per se* in the air to produce the haze which I myself noticed. For when staying at an elevation of 2,800 ft. during the summer of 1890, when three Lestes occurred, the atmosphere appeared peculiarly clear and luminous on every occasion; very different from the haze usually seen from Funchal. From the above considerations, however, the evidence seems to prove that there is an unusual amount of dust floating in the atmosphere. During a Leste in September 1890 I made an ascent to an elevation of 4,500 ft., and an observation I happened to make on that occasion may perhaps help to explain the nature of this haze. The haze on that day over sea and land was very marked, but the Desertas were just dimly visible. At an elevation of 2,300 ft. (Camacha) all the higher points around were, however, perfectly clear, and the atmosphere quite luminous and free from all haze. It was only on looking down to lower levels that the haze was apparent. Now, on making a further ascent to an elevation of about 3,500 ft., curiously, all the highest points of the mountains in the Desertas began to stand out perfectly clear and distinct, while the whole lower thousand feet or so were barely visible, causing a remarkable effect. The difficulty in accounting for the haze lies in the fact that we cannot suppose it is of the nature of an ordinary sea mist; for neither could the temperature of the sea bring the air in contact with it to anywhere near the dew point, nor is there known to be any counter-current of cool air during the height of the Leste either on land or sea to lower the temperature of the whole body of air to the point of precipitation. But now bearing in mind the extremely rapid evaporation which is going on from the sea under the existing conditions of temperature and humidity, secondly, the increased quantity of dust floating in the air at the time, and thirdly, the fact recently demonstrated by Mr. Aitken that a solid nucleus is always necessary for the condensation of watery vapour in the forms of fogs, mists, and clouds, may not the largely increased number of dust particles in the air have the power of attracting around themselves, and thus condensing some portion of the watery vapour arising from the sea in such large quantities and thus producing the haze, which the simple presence of impalpable dust in the air is not capable of doing? Thus while the haze is visible at the sea level and up to a certain altitude, at higher elevations, where the dry air still persists, the air remains clear and luminous.

We will now pass on to consider the conditions of temperature and humidity accompanying a Leste. The temperature rises considerably, but never reaches the intense heat experienced during the hot winds of Southern Australia or South Africa. The highest temperature reached is rarely much

above 90°, but this temperature being accompanied by a wind of considerable force and of great dryness, is decidedly felt both by the inhabitants and also by the vegetation of an island climate with such an equable temperature. The highest temperature I can find recorded is 93°. During a Leste lasting from July 26th to 29th, 1882, recorded by Dr. Langerhaus, the thermometer rose 90·4°, and the highest minimum was 74·5°. The minima are not as a rule so much higher than the average minimum as might have been expected with a continuance of the wind; a result due probably to the much less force with which it usually blows during the night, and to the rapid radiation taking place from the dryness of the air.

The relative humidity shows a marked variation from the mean, falling sometimes as low as from 20 to 25°/₀. In the above-named Leste recorded by Dr. Langerhaus in 1882, the relative humidity was as low as 19°/₀. It is remarkable how suddenly the change may take place. For instance, on July 9th, 1890, at 5 p.m., the dew was falling fast, the dry and wet bulbs standing respectively 61° and 59°, indicating a relative humidity of 88°/₀, yet at 7.30 p.m. the dew had entirely disappeared and the relative humidity had fallen to 48°/₀, there being 12° difference between the readings of the dry and wet bulbs.

The maximum reading in the sun by the blackened bulb *in vacuo* indicates during a Leste only a slightly higher temperature than on ordinary fine and clear days, though the heat of the sun feels very scorching, but the maximum solar intensity is usually less than on such a day; thus during a Leste in June 1890 at Funchal the shade maximum was 87°, the maximum in the sun 139°, and the maximum solar intensity therefore 52°; while on a fine day, *e.g.* June 21st, with the considerable humidity of 71°/₀, the shade maximum was 73·5°, the sun maximum 134°, and the solar intensity 60·5°. At an elevation of 2,800 ft. the same result obtained. On September 1st, with the difference of 18° between the dry and wet bulbs, or a relative humidity of only 34°/₀, the solar intensity was only 52°, while on a clear day, with a relative humidity at noon of 72°/₀, the solar intensity was 65°. Very similar results, though generally with slightly lower solar intensities, were obtained when the readings of the sun and shade temperatures were taken synchronously at noon, which is, perhaps, a more accurate method than taking the maximum of each for the day.

From these observations it would appear that the amount of moisture does not lessen the heat of the sun as much as would have been expected, or else on the occasion of the Leste the large amount of other suspended matter in the air interferes equally with it. The amount of ozone in the air is much diminished during a Leste. In a Leste of July 1890, during the three days of its most marked prevalence, the mean was 2·1 in a scale of 0—10, whereas on the six previous days it averaged 4·5, or more than twice as much. When the Leste has blown itself out it is almost invariably followed by rain or a thick mist, for as it is gradually replaced by the cooler North-east wind, which is the prevailing wind all the year round in Madeira (*vide* Dr. Buchan's *Report on Atmospheric Circulation—Challenger Expedition*), the temperature

falls, and the large amount of moisture absorbed into the air becomes condensed. This is well seen in the Leste which occurred in June 1890, and of which I append an account with others illustrating the foregoing statements.

TABLE I.

LESTE OBSERVED BY DR. LANGERHAUS AT AN ELEVATION OF 1,850 FT.

Date.	Temperature.		Relative Humidity.		
	Min.	Max.	9 a.m.	12 Noon.	9 p.m.
July 1882.	°	°	%	%	%
26th	65·6	83·8	70	73	47[1]
27th	71·7	84·9	47	33	46
28th	74·4	90·5	19	23	66
29th	70·3	79·1	67	63	66

[1] Leste set in suddenly between noon and 9 p.m. on 26th.

TABLE II.

LESTE OF SHORT DURATION, NOT EXPERIENCED TO ANY EXTENT IN FUNCHAL, SHOWING SUDDEN ONSET AFTER SUNSET.

Observations taken at Camacha at elevation of 2,300 ft.

July 9th, 1890.—Min. 46°·5. Max. 72°·5.

	Dry Bulb.	Wet Bulb.	Rel. Humid.	Dew Point.
	°	°	%	°
10 a.m.	69	62·2	65	56·7
5 p.m.	61	59	88	57·3
7.30 p.m. ..	59	47	43	36·3
9 p.m.	53	45	55	37

Grass, &c. wet with dew at 5 p.m., but all disappeared and quite dried up by 7.30 p.m. Cloudless day and Wind 0. Vane showing NE.

July 10th.—Min. 46°. Max. 77°·5.

	Dry Bulb.	Wet Bulb.	Rel. Humid.	Dew Point.
	°	°	%	°
9 a.m.	74	55	31	41·1
12 Noon ..	75·6	55	28	40·4
5 p.m.	69·2	53·4	36	40·7
8 "	61	48	41	36·7

Wind E. Force 2. Clouds 0, except for undefined bank over Desertas. Mountains very clear.

July 11th.—Min. 54°·5. Max. 74°.

	Dry Bulb.	Wet Bulb.	Rel. Humid.	Dew Point.
	°	°	%	°
10 a.m.	69·5	63·5	68	58·3
12 Noon	72	64	61	58
5 p.m.	66	62	78	58·8

Leste gone. Wind NNE. Slight drizzle in evening with clouds travelling from NE.

TABLE III.—LESTE OF JUNE 5TH–9TH, 1890.

Observations taken at Funchal at elevation of about 350 ft. A dense mist supervening on its subsidence.

Date.	Temperature. Min.	Max.	10 a.m.	5 p.m.	Max. in Sun.	Relative Humidity. 10 a.m.	1 p.m.	5 p.m.	Clouds 0–10. Mng.	Evng.
June 1890.	°	°	°	°	°	%	%	%		
5th	58·5	75	70	72	129	69	..	65	0	0
6th	64·5	84	80	79·8	136	39	41	48	0	0
7th	68	87	83·2	79	139	39	34	49	0	0
8th	64·8	76	73·4	72·2	130	72	..	78	½	0
9th	61·5	71	67	67·8	136	83	..	84	10	0

Date.	Ozone. Mng.	Evng.	Wind. Direction. Mng.	Evng.	Force. Mng.	Evng.	Barometer.	Hours of Sunshine, Jordan's Recorder. h.	m.	Solar Intensity.
June 1890.							Ins.	h.	m.	°
5th	4	2	NE	NE	1	0	30·120	12	45	54
6th	3, 5	1	ENE	E	4, 5	2	30·171	12	35	52
7th	4	1	E	E	3	1	30·048	12	20	52
8th	3	1	E	E	1	0	30·075	12	25	54
9th	6	2	NW	.. ?	1	0	30·083	8	10	59

June 5th.—Leste reported from Camacha, but not affected this position yet. Splendid cloudless day. Mountains little hazy. Desertas indistinct. Fine sunset and red after glow.

" 6th.—Leste set in during night. Very clear, with only slight haziness on land, more at sea. Rough sea. Desertas just visible, with some stratus lying over them. Wind falls to calm in evening, rising again at 10 p.m. to force 4 and 5.

" 7th.—Leste continues. Hazy at sea, but Desertas visible. Slight undefined bank of clouds over them, clearing off midday. At sunset low lying bank completely hides their bases, while upper half of Islands remains clear.

" 8th.—Leste diminishing. Very clear, except for low lying bank to SE. Horizon at sea hazy.

" 9th.—Thick foggy morning, but clearing at 11 a.m.; remains misty over the sea. Very calm.

TABLE IV.—LESTE OF JULY 19TH AND 20TH, 1890.

Observations taken at Camacha at an elevation of 2,300 ft. A return of it on 22nd and 23rd, after subsidence on the 21st. A fall of 17° from morning of 20th to 21st.

Date.	Temperature. Min.	Max.	10 a.m.	12.	5 p.m.	7 p.m.	Blackened Bulb in vacuo. Max. in Sun.	Relative Humidity. 10 a.m.	12.	5 p.m.	7 p.m.	Barometer. (Aneroid)[1].
July 1890.	°	°	°	°	°	°	°	%	%	%	%	Ins.
18th	54·5	66	63	..	62·8	..	130·5	68	..	60	..	27·56
19th	52·	83·5	74·8	82	73	71	141	45	33	38	37	27·57
20th	62	82·2	78·4	80·8	74	68	138	35	33	40	56	27·63
21st	54	71·5	61·8	67·2	66·2	60	133	68	68	50	77	27·50
22nd	56	77	73	..	71	..	136	42	..	40	..	27·50
23rd	63·5	78	76·6	..	70·6	..	136·5	49	..	67	..	27·50

[1] Barometer uncorrected for elevation or temperature.

TABLE IV.—*Continued.*

Date.	Clouds 0–10.		Wind. Direction.		Wind. Force.		Ozone.		Solar Intensity.	Hours of Sun.
	10 a.m.	5 p.m.	10 a.m.	5 p.m.	10 a.m.	5 p.m.	Mng.	Evng.		
July 1890.									°	h. m.
18th	2	0	NE	NE	4	4, 2	7	2	64·5	9 45
19th	0	0	ENE	E	2	3, 2	4·5	1	57·5	11 30
20th	0	0	E	E	2	3	2	1	56	11 10
21st	1	0	NNE	NE	3	3, 6	5	3	61·5	11 20
22nd	1	0	ENE	ENE	4	3	4	2	59	11 25
23rd	0	0	NE	..	1	0	3	1·5	57·5	11 20

July 18th.—Strong breeze all night, dull morning then clearing Desertas invisible, but air clear and no haze at this elevation, red glow at sunset.

„ 19th.—Distinct Leste. Hazy at sea. Desertas invisible all day. Very clear, except undefined bank of cloud to eastward.

„ 20th.—Low but dense bank of haze or mist to E and SE, otherwise very clear. Desertas invisible. Curious effect of mist rising from the sea like puffs of smoke which gradually dispersed as they rose in the air.

„ 21st.—Wind more Northerly. Fresh and cool. Desertas still invisible. Cloudless except for some cumulus over bank to SE. A fall of 17° at 10 a.m. from temperature of 20th. Wind rising to nearly gale force in evening.

„ 22nd.—A return of Leste.

„ 23rd.—Warm night. Splendid clear day. Wind backing to N. Leste passing off to hot summer weather. (?)

NOTE.—Minimum falling on 25th to 48·5° F. corresponding to its rise from 46·5° on 15th, 47·5° on 16th.

TABLE V.—LESTE OF FEBRUARY 17TH, 1891.

Date.	Temperature. Min.	Max.	10 a.m.	Noon.	5 p.m.	Max. in Sun.	Relative Humidity. 10 a.m.	Noon.	5 p.m.	Barom. cor. for Elevation and Temp.	Clouds 0–10. 10 a.m.	5 p.m.
Feb. 1891.	°	°	°	°	°	°	%	%	%	Ins.		
15th	52	67·5	63·4	..	61	122	61	..	67	30·094	0	0
16th	51	69	64·4	68	62	124	50	54	58	36·124	1	1
17th	58·5	71·8	68	71	61·8	120	47	37	64	30·082	1	0
18th	51·8	67·5	62	..	61	120	68	..	62	30·086	1	1
19th	59	66·5	63	..	60·4	124	76	..	80	29·972	8	8

Date.	Wind. Direction.		Wind. Force.		Solar Intensity.	Hours of Sun.	Remarks.
	10 a.m.	5 p.m.	10 a.m.	5 p.m.			
Feb. 1891.					°	h.m.	
15th	NE	NE	2, 3	2	54·5	9·45	15th.–Cloudless day. Fresh NE breeze. Mountains very clear. Desertas rather hazy.
16th	ENE	ENE	2, 4	2	55	10	16th.—Desertas invisible and hazy at sea.
17th	E	NE	2, 1	2	48	9·05	
18th	E	E	3	2	52·5	9·35	
19th	SE	S	2	2	57·5	3·35	

REMARKS (*continued*).

16th.—Fresh Easterly wind with crystal waves at sea. 17th.—Desertas quite invisible. Very hazy at sea. Low undefined clouds to SE, topped by a few cumuli in morning. Wind falls to almost dead calm midday, when Relative Humidity is only

37 per cent. and sky very *grey*. No real blue to be seen. Cooler and damper wind from NE sets in at 4.30, and thermometer falls 4°. The Humidity increases 20 per cent., but at 7 p.m. the Relative Humidity had again fallen to 43 per cent. Sun set in thick haze. 18th.—Less hazy, and Desertas faintly visible. 19th.—Leste quite left us. Soft S wind. Large and heavy cumulus. Rain ·80 in. during night.

TABLE VI.

LESTE OF FEBRUARY 19TH–21ST, 1889. A MARKED WINTER LESTE.

Date.	Temperature.				Rel. Humid.		Hours of Sun.	Barometer corrected. 9 a.m.	Ozone	
	Min.	Max.	10 a.m.	5 p.m.	10 a.m.	5 p.m.			a.m. 10	p.m. 5
February 1889.	°	°	°	°	%	%	Hours.	Ins.		
18th	58	64	62	60	74	77	3	30·086	3	..
19th	53	76	73·2	70·6	42	37	10·45	30·219	..	..
20th	66·5	75·5	75·4	68·8	41	47	10·45	30·216	05	2
21st	54·5	70	65·8	60·2	62	71	9·30	30·120	3	..
22nd	52·5	64	9·60	58	68	76	7	29·962	..	..

Date.	Clouds.		Wind. Direction.		Wind. Force.		Remarks.
	10 a.m.	5 p.m.	Mg.	Ev.	Mg.	Ev.	
February 1889.							
18th	9	7	SE.	SE.	1	1	Hazy at sea.
19th	0	0	E.	E.	1	0	Cloudless but very hazy at sea.
20th	0	0	E.	E.	2	1	No clouds but bank of undefined clouds to SE.
21st	1	7	E.	..	1	0	
22nd	5	6	E.	ESE.	1	3	Cirro-cumulus.

On the 23rd rainfall ·03, on 24th 1·27 inch.

DISCUSSION.

Inspector-General LAWSON said that he had had very little experience of the "Leste," although he well remembered that, between Madeira and the African coast, the vessel he was in was caught by a squall as this wind was setting in and narrowly escaped being capsized. He had had some experience of the Sirocco at Malta, which differed in character from the "Leste." In Natal, too, a North-east wind was sometimes experienced which bore a very close resemblance to the Maltese Sirocco. During summer a South-westerly wind, of high temperature, with a very low dew point and clear weather, is occasionally met with at Malta, and more frequently over Sicily and the south-west coast of Italy, which is described by writers as the Sirocco: but at Malta, the wind so denominated comes from the South-east later in the season, is rather cooler than the mean temperature of the season, with cloudy hazy weather, so that the horizon is often invisible, and moisture is deposited copiously on all exposed surfaces. Meat putrifies rapidly during the prevalence of the latter wind, and wine bottled during it does not clear. It is obviously derived from the Indian Ocean, while the Sicilian Sirocco comes from the African desert. At Natal, during January and February, a wind from the North-east is frequent, presenting the characters of the Malta Sirocco, there being cloudy hazy weather, with much moisture in the atmosphere.

Dr. BARNES said that he should much like to know what effect the "Leste" produced upon the health of the residents at Madeira.

Mr. SYMONS said that it would be of considerable interest to know whether,

when the "Leste" prevailed and the atmosphere was so full of dust, any twilight effects, such as those seen after the Krakatoa eruption, were observed; of course the sand particles were very different from those of pumice.

Inspector-General LAWSON said that at Sierra Leone the brown dust brought by the wind from the desert never attained a greater altitude than 700 or 800 ft. above sea-level, so that it was not sufficiently high to cause any sunset effects.

Mr. TRIPP said that differences of 9° and 10° between the dry and wet bulbs did not indicate such dryness as might be expected from a wind originating in the Sahara, and he supposed this was owing to its having passed over some 300 miles of sea. In other countries dry winds came from the direction of the greatest heated surface of land, and their direction varied accordingly. In British Kaffraria, Cape of Good Hope, he had noticed the dry bulb at 100° and the wet at 75°, this indicating a relative humidity about 28 %. This was in the afternoon at about 5.30. His observations were taken principally in the morning about 9 a.m., and he had then repeatedly seen differences of over 20°, indicating a relative humidity of 30% or over. He had, however, never noticed anything equal to Dr. Langerhaus' observation of 19%. He had not, however, searched for this phenomenon, and had systematic observations been made in this direction perhaps greater degrees of dryness than those he had noticed might have been discovered. With regard to duration, the most decided instance he had seen had been a succession of four mornings with a relative humidity ranging from 31 to 53, and giving an average of under 44%. These hot winds were much felt by vegetation, and were often succeeded by dust and rain storms with thunder and lightning; they generally came from the North-west.

The PRESIDENT (Mr. LATHAM) said that the sunset afterglows which he had seen in Egypt were magnificent, but whether they were due to the presence of dust in the atmosphere or not he was unable to say. At Bombay, too, the sunsets were very beautiful, but inland and in the neighbourhood of the Himalayas such sunsets were never seen.

A CURIOUS CASE OF DAMAGE BY LIGHTNING.

BY ALFRED HANDS, F.R.Met.Soc.

(Plate VII.)

[Received May 20th.—Read June 17th, 1891.]

ON the afternoon of Sunday, April 5th, 1891, a severe thunderstorm passed over South Staffordshire, and during Divine Service Christchurch, commonly called the Forest Church, Needwood, was struck by lightning, and some slight damage was done.

I received instructions to examine and test the lightning conductor and report as to the cause of the accident. On examination I found the damage, although only of a trifling character, possessed some points of both an uncommon and instructive character, and I thought therefore that a description might be of interest to the Fellows of this Society.

The church, which is a small building having a tower at the western end, stands on high ground, and has several trees round it. I have prepared drawings which will serve to illustrate the church and the nature of the damage which was done, (Plate VII.) No. 1 is the south elevation; No. 2

is the eastern end, while No. 3 is a ground plan of the building. Nos. 4 and 5 show details which I shall explain later on.

The tower, which has four pinnacles, each surmounted by a small wrought iron vane, is about 64 ft. in height, while the ridge of the roof is 34 ft. from the ground line. The length of the building without the tower is 60 ft.

The conductors, which had been erected, I believe, about seven years before, consisted of a main down conductor of copper tape 2 ins. by $\frac{1}{16}$ in. carried from the south-east pinnacle to earth, while each of the other pinnacles had a branch conductor of copper tape 1 in. by $\frac{3}{32}$ in. carried to the main down conductor. All these conductors were connected to the vane rods by copper bands made in two halves fastened by copper bolts and nuts, and to these bands the tapes were secured by copper rivets. The earth connection was made by a copper-plate 3 ft. by 3 ft. by $\frac{1}{8}$ in. in accordance with the instructions formulated by the "Lightning Rod Conference."

Unfortunately no one saw the lightning strike the church, the only person in the neighbourhood outside the building at the time being a man who had taken shelter from the rain under a yew tree some twelve or fifteen feet from the conductor, and he was so placed that he could only see the lower part of the building. We must therefore take our ideas of what occurred by deduction from the traces the discharge left in its course.

The main conductor at its junction to the vane (*a* Fig. 1) was disconnected, the copper bolts fixing the band or collar and also the copper rivets which connected the tape to the band being broken, but there were no marks of fusion. Further down (*b*. Fig. 1) a spark passed between the conductor and the lead flashing, which runs along the edges of the slates about 2 ft. away, damaging the stone parapet in its course. Lower down (*c*. Fig. 1), a few inches from the ground, a spark passed through the wall into the building. Along the ridge of the roof sheet lead is laid in lengths overlapping one another, and this lead was turned up at every alternate joint. The rain-water gutters along the southern side were broken and thrown down in two places, and the rain-fall pipe at one side of the end of the building (*d*. Fig. 2) was broken at the joints and also thrown down. The corresponding fall pipe on the other side had slight damage at the joints.

The most curious part of the damage, and one which appears to me inexplicable, was on the top of the tower. As usual with such places, it is covered with lead, which was in connection with the lightning conductor. Round each of the four pinnacles there is an iron band with a stay rod of $1\frac{1}{4}$ in. iron from it to the lead flat, where it is secured by a $\frac{5}{8}$ in. iron bolt. The lead is $\frac{1}{16}$ in. in thickness: beneath that there is 1 in. floor boarding, then there is a space of 3 ins., and below that there is a 9 in. rafter through which the bolt rod passes. Just under this stay rod there was a hole about an inch in diameter, made as if it had been punched, the edges of the lead being turned downwards and the wood floor board splintered.

No further damage was done here, but the buttress at the south-east corner of the building (*e*. Fig. 2) was broken through by a discharge which took place between the fall-pipe and the railings on the south side of the church,

and further on (*f.* Fig. 1), where the metal continuity of the railings was broken by a gate being open, a discharge passed through the brick step slightly disarranging it.

On the opposite side of the building there are also railings, and discharges passed from these to earth in three places, cutting channels through the grass somewhat as shown in Fig. 5.

As previously mentioned, a spark passed into the church at the base of the conductor, and, of course, I at once suspected that there was metal behind there; but I may mention as an instance of how people who do not understand the subject may overlook important details, that I was assured that there was no metal whatever. On examination, however, I found that just inside the wall, which is 18 ins. in thickness and therefore within about 2 ft. of the conductor, there was fibre matting the ends of which lying against the wall were bound with lead, about equal in quantity to a 1 in. diameter pipe flattened out. There were two lengths of this binding placed end to end, then there was a break of 4 ft. 11 ins., when the binding commenced again and continued past the centre, where there is a step between the tower and the body of the church.

Just at the corner where the spark passed (*c.* Fig. 1), close to the wall and on the lead was a hassock through which the spark tore its way, driving it 40 ft. up the church; then the discharge was conducted by the two lengths of lead binding to where the break occurred. There was a wooden seat which was the next best conductor available, and the discharge passed through the lower part of it, moving it by the impact of the blow 22 ins. out from its position. Further on, where the lead bindings commenced again, it left the seat and was conducted to the step, where it struck through the stone to a large iron furnace formerly used for heating the church. This furnace is approximately 8 ft. high, 2 ft. 6 ins. deep, and 2 ft. 6 ins. wide, and is about an inch in thickness.

As I have said the whole of the damage was of a trifling character, the hole through the wall being merely large enough to allow of one finger being inserted, and the damage to the step being about the same.

On testing the lightning conductor, I found the connections between the tapes and the vane rods had become bad owing to oxidation, the resistance in one case being over 2,000 ohms. The resistance of the earth connection was 14 ohms.

As regards this resistance to earth, I may say that it is still an undecided question as to what should be the maximum resistance allowable in the earth connection of a lightning conductor. From my experience in testing, I am of opinion that for every five that would be found to have a lower resistance than this, 95 would be found to be higher. It may sound high to electricians who have to deal with electricity at low tension, but for high potential, such as a discharge of lightning, it would form comparatively no obstruction. It is such a resistance as would under ordinary circumstances be given by a copper-plate 3 ft. square bedded in coke. Under very favourable circumstances, that is in a very damp locality, I have found that a copper-plate this

size laid 2 ft. under ground has given a resistance of a fraction of an ohm merely, while in a light porous soil I have known a plate 10 ft. by 3 ft. 6 ins. at a depth of 10 ft. show a resistance of 30 ohms.

Undoubtedly a resistance of half an ohm is better than two ohms, but in a case such as this where there are no gas or water pipes, or other metals having a low resistance to earth, such a small resistance as 14 ohms cannot be considered sufficient to explain a flash passing from the conductor to other metals.

If it was absolutely necessary for the "earth" to be below 14 ohms, then at least 95 per cent. of the conductors in England would have to be condemned as inefficient. Personally, I think that the question of the maximum resistance allowable depends upon what other paths to earth are available. For instance, a plain stone structure without a particle of conducting matter in its composition besides the lightning conductor would be protected by a comparatively high resistance; while one with gas and water pipes, which necessarily have admirable earth connections, should have a conductor with a nominal resistance only.

I have for a long time considered that it is possible that where a conductor is carried close to metals either inside or outside a building, that a spark may pass no matter how low the resistance to earth, indeed it is obvious that the "Lightning Rod Conference" took this possibility into account when they recommended that all metals in the neighbourhood of the conductor should be brought into metallic contact with it. Great care, therefore, should be taken by those fixing conductors to see that they are not placed near any other metals, either inside or outside the buildings, which it may not be convenient or expedient to connect them to, and the owners of the buildings should take care that no metals are placed in the neighbourhood of the conductors after they are fixed.

In the present case there was in the vault under the tower a large mass of iron. This would have been perfectly safe, but that a line of metal had been recently laid from close to this furnace to within about 2 ft. of the conductor, and this was equivalent to reducing the distance between the furnace and the conductor very considerably.

At the time that the conductor received the discharge of lightning, the copper tape and the metals inside the church would owing to inductive action be in oppositely electrified states, and consequently a spark would pass to restore the equilibrium.

It is extremely difficult to say what exactly was the nature of the discharge at Needwood Church, but I am convinced by several details that it was exceptionally severe. There are circumstances pointing strongly to an upward discharge of lightning, but this is not fully borne out; while the remark of the man I have referred to that he saw a large ball of fire come down the tower, might lead us to imagine that the phenomena might be connected with "globular" lightning.

After a careful examination of the building I am inclined to think that it was either struck by two flashes simultaneously, or by a discharge which

bifurcated, part falling on the south-east pinnacle of the tower, and part on the ridge of the roof. The first part was conducted down the copper tape to earth, but a spark passed through the wall to the binding of the matting, as I have already described. The other part divided, part passed along the lead on the roof and sparked across the parapet to get to the conductor, the remainder going to earth by the rain water gutters and fall pipes; but it is evident that nearly all passed down on the south, and very little on the north side. It was raining heavily at the time, and no doubt water had penetrated under the lead at the joints along the ridge, so that the heat generated by the resistance at the joints might turn the water into steam and so blow up the edges by the force of the explosion.

The damage to the rain water pipes and gutters would probably occur in a slightly different way. This kind of damage takes place in nearly every case where rain pipes act either as conductors or auxiliary conductors to a flash of lightning, and I have heard several explanations, but none that seem quite feasible. It should be borne in mind that the gutters and pipes are badly put together, no attempt being made to make the joints electrically good, in fact there is an enormous resistance in some of them almost from the moment they are put up. There is sure though to be one point in each of the joints where the resistance is less than in the rest of the joint, and an electric discharge in passing from one length of pipe or gutter to the next, chooses this path of least resistance and passes across in the form of a spark, so generating heat at this point, and this heat is so great and is generated in such an inconceivably short space of time, that before it can be conducted along the metal, expansion takes place at one part, which, as the metal is brittle, causes the iron to crack and the piece broken off springs away to a distance. I have often tried to find one of the pieces to look for marks of fusion, but have never been successful as they are probably projected to too great a distance. In this case I found one piece of gutter which, although it was not broken, shows signs of fusion such as I expected.

The discharge that took place at the back of the church between the rain-fall pipe and the iron railings is, I think, explicable in precisely the same way as the spark which passed between the conductor and the furnace inside the tower. In this case the rain-fall pipe was acting as a lightning conductor, but with a bad earth connection, the resistance to earth being over 1,100 ohms.

In each of these cases of side flash I consider it is as correct to say that sparks passed from the isolated masses of metal to the conductors, as it is to say that they passed the other way, indeed in the case of the last named discharge the injury to the rain-fall pipe (if really caused by lightning) seems to prove that the discharge was from the railings, and was therefore entirely an induced discharge and did not exactly form part of the lightning flash.

On the other side, it is to be remarked that the railings, although precisely the same distance from the fall pipe on that side, did not receive a spark from the pipe. Hence the charge that passed down this side must have

been much less than that on the south side. As may be expected, the earth connection of this fall pipe was even worse than the other.

There would, however, still be the induced charge in these railings to be got rid of, and consequently on this charge being liberated, it would go direct to earth, cutting the curious furrows in the grass which I have described. I take the intensity of this induced charge to be a proof of the exceptional violence of the inducing charge.

The lightning conductor could not be passed as in a satisfactory condition, owing to the bad joints at the connections to the vanes. Besides this, there were some bad bends, the tape being carried down from the pinnacle to the lead flat and then up again over the parapet. Again, the conductor ought to have been connected to the lead flashing on the roof where it was carried near it.

I contend, however, that none of these faults were sufficient to account for the spark that passed at *c*. Fig. 1, and that the sole cause of the discharge there was the lead bound matting having been laid so close to the conductor.

Although the accident to Needwood Church may be considered to be a case of the partial failure of a lightning conductor, it must be borne in mind that it carried off the bulk of a discharge which, had there been no conductor, would have probably wrecked the tower and caused serious loss of life by the masonry falling through the roof upon the congregation. As it was, the whole of the damage would be set right by the expenditure of a few pounds, and would be covered by the insurance policy.

As regards the body of the church, we may consider that it was never protected from lightning. No expert would say that a conductor on the tower, however perfect, would afford absolute protection to the other end of the church. As a rule, however, those having the management of such buildings prefer to protect the tower or spire, which is the part most likely to be struck, and leave the rest to chance, owing to the extra cost which would be entailed by completely protecting the whole building.

Of course, where there are rain water pipes and gutters on the building, a discharge of lightning must divide itself between them and the conductor in proportion to their respective capacities ; and therefore, unless the joints were made electrically good, or continuous conductors were carried along them in order to bridge the points of resistance, there is always a danger of some of them being broken. Such very slight damage as this, however, need scarcely be considered, I think, when we take into account the dreadful havoc and ruin which lightning conductors, properly applied and fitted, will prevent.

DISCUSSION.

Mr. Symons said that a case of damage by lightning bearing a very close resemblance to that which had been so thoroughly discussed by Mr. Hands, was to be found in the *Report of the Lightning Rod Conference* (p. 217). In that instance Carmarthen Church, which was provided with a conductor, was damaged by lightning, and the disruptive discharges which caused the damage were due to

the conductor being placed in close proximity to a gas main, but not connected with it, the lightning in its passage down the conductor naturally glanced off to the gas-pipe because it afforded a good earth. The conductor, however, as in the case described by Mr. Hands, doubtless saved the church from very serious damage. It was one of the recommendations of the Lightning Rod Conference that all the metal work in a building should be in perfect connection with the lightning conductor. In erecting a lightning conductor it was absolutely necessary that every part of the work should be thoroughly well done. He agreed with Mr. Hands that the present case was not an instance of the occurrence of side lightning, and that the east end of the church was not in the area of protection afforded by the lightning conductor.

Prof. Mascart remarked that the resistance of 14 ohms was far too great, and that it was desirable to utilise gas and water mains in forming the earth connection for lightning conductors. In France it was now the common practice to substitute a long tube buried in the earth for the small plate, usually employed in England as the earth connection. The lightning conductors fixed on the Eiffel Tower were provided with tubes 10 metres long, buried so deeply in the soil that they were always damp.

Mr. Ellis said that this paper formed an excellent object lesson to himself, as he was now concerned in putting a new lightning conductor to the parish church at Greenwich, and had received valuable information from Mr. Hands' clear account of the damage done to the church at Needwood. It was a comforting thing to find that even an imperfect conductor might, to a great extent, do its duty. The old conductor at Greenwich Church had been carefully examined, the connections and joints were found to be in a bad condition, and the conductor was about to be entirely renewed.

Mr. Dines drew attention to the case of a well-known abbey in England where the end of the lightning conductor was immersed in water in a sealed iron tube buried in the ground.

Mr. Stanley said that in tropical countries iron rods about $1\frac{1}{4}$ in. in diameter were preferred to copper band lightning conductors. The terminals were pointed brass rods, tipped with platinum. He did not know which metal formed the best conductor under the conditions, but iron was probably cheaper. In the case of damage described by Mr. Hands it seemed that the electrical discharge was too great for the conductor to efficiently carry it off.

Mr. Symons said that he was not prepared to discuss the relative merits of iron and copper as lightning conductors, but doubtless the reason that copper was not used in the countries referred to by Mr. Stanley was because, being of greater value than iron, it was much more likely to be stolen. An iron conductor afforded for the same outlay a larger surface than a copper one, but in a damp atmosphere like that of the British Isles iron rapidly rusted and soon spoiled.

The President (Mr. Baldwin Latham) said that in India iron was almost universally used for lightning conductors, chiefly because the natives stole copper. He much preferred a strip of copper to a rod of iron. In the case of tall chimney shafts a lightning conductor did not give an immunity from lightning stroke, and considering the large amount of iron, such as boilers and furnaces, which was usually to be found in large works, and generally unconnected with the conductor, he was surprised that cases of damage from lightning were not much more frequent.

Mr. Hands, in reply, said that he thought it would not be possible to connect all metal work inside and outside a building with the lightning conductor. The better way would be to examine the interior of a building first, to ascertain the amount and position of the metal work, and then arrange that the conductor should be placed at a sufficient distance from such metallic substances. He could not agree with Prof. Mascart that the resistance of the earth connection should be less than one ohm, as in districts with a naturally dry soil the cost of carrying the conductor to a sufficient depth to obtain such a resistance would be greater than anybody would care to incur.

On the Mean Temperature of the Air at the Royal Observatory, Greenwich, as deduced from the Photographic Records for the Forty Years from 1849 to 1888.

By WILLIAM ELLIS, F.R.A.S.

[Received May 11th.—Read June 17th, 1891.]

The main object of the present paper is to communicate to the Royal Meteorological Society a table of mean monthly temperatures deduced from the Greenwich photographic records, but it has appeared to me that it might be desirable and useful to include also some account of the way in which at different times Greenwich mean temperatures have been formed.

On the establishment of the Magnetical and Meteorological Department of the Royal Observatory, Greenwich, in the year 1840, eye observations of air temperature were made every two hours, commencing in November of that year, until the year 1847, excepting on Sundays and some other days, when a few observations only were taken. In 1848 observations were made six times daily, but fewer on Sundays, and since 1849 usually four times daily. The continuous photographic record is available since 1849. Readings of self-registering maximum and minimum thermometers have been taken throughout.

The mean daily temperatures given in the Greenwich volumes until the end of the year 1847 depend upon the twelve two hourly eye observations of each day, there being during this period no Sunday results. In 1848 they were deduced from the six eye observations only, corrected for diurnal inequality, and from 1849 to 1876 from the four eye observations, corrected for diurnal inequality, combined with the mean of the readings of the self-registering maximum and minimum thermometers, corrected for the excess of such mean above the true mean, these various corrections being determined and applied in the manner indicated by Mr. Glaisher in his paper in the *Philosophical Transactions* for 1848.[1] Commencing with the year 1848 the fewer observations of Sunday have been utilised to form values for that day. The mean daily temperatures contained in the Meteorological Report communicated to the Registrar General, for publication in his *Weekly Return of Births and Deaths in London*, are, up to the year 1876, the same as those that appear in the Greenwich volumes. In the year 1877, at my suggestion, a change was made, the mean daily temperatures given in the Greenwich volume having been since that year deduced from the photographic records alone, each daily value being the mean of 24 hourly values taken from the photographic register, and reduced to the reading of the dry bulb thermo-

[1] *On the Corrections to be applied to the Monthly Means of Meteorological Observations taken at any hour, to convert them into Mean Monthly Values.*

meter of the revolving stand. In the case of accidental failures of register, which during this period were not numerous, eye observation values were employed in order that the whole period should be completely represented. But for the report supplied to the Registrar General values deduced entirely from the eye observations had to be as before employed, since it was not possible to deal with the photographs in the limited time available, at the end of each week, for preparation of the weekly report which has to be completed on Monday morning for the week ending the previous Saturday at midnight. Commencing, however, with the year 1878, new corrections for diurnal inequality and for the excess of the mean of the maximum and minimum thermometer readings above the true mean were determined from the Greenwich twenty years' meteorological reductions,[1] varying the corrections through each month as necessary, instead of using one set of corrections through the month. The corrections for diurnal inequality are to be found in the twenty years' reductions, but the new corrections to the mean of the maximum and minimum, to reduce it to the true mean as deduced from 24 hourly values, have never been published. It is proposed to add them at the end of this paper.

The twenty years' reductions contain a discussion of the photographic records of air temperature from 1849 to 1868. As there published, the monthly means (Table 52) are not corrected for the effect produced by the omission of days on which there were no available registers, and which were more numerous during this period than in later years. These means I some years ago corrected for my own use by including for omitted days values derived from the eye observations, but the corrected values were never published. More recently the photographic records for the years 1869 to 1876 have been also discussed, and the results, duly corrected for the effect of omitted days, in this period few in number, have been included in an appendix to the Greenwich volume for 1887, thus completing the reduction of the photographic records from 1849 to the present time, since beginning with 1877, as beforementioned, the mean daily temperatures given in the annual volume are those deduced from the photographs, which are in all cases reduced to the reading of the dry bulb thermometer of the revolving stand.

It is now therefore possible to form a table of monthly means of Greenwich temperatures beginning with 1849, depending essentially on the photographs, and completely representing the period, since eye observation values have been throughout included for omitted days, which, more numerous in earlier years, were comparatively rare in later times.

It is proposed to undertake shortly at the Royal Observatory the preparation of tables of meteorological averages, to include amongst other things averages of meteorological elements for days of the year. The work has, indeed, been commenced, although no very great progress has been yet made with it owing to the pressure of other work which has to be first cleared off.

[1] *Reduction of twenty years' Photographic Records of the Barometer and Dry-bulb and Wet-bulb Thermometers, &c., made at the Royal Observatory, Greenwich.*

But as reference is frequently made to Greenwich air temperatures, it has occurred to me that, as the monthly means already exist, scattered, however, through many volumes, it might be useful to meteorologists at once to collect them into one table for immediate publication. The results from 1841 to 1847, depending on two-hourly eye observations, could not be here included, it being a part of the scheme just spoken of to complete the daily series for that period by forming values for Sundays; and as the year 1848, if included, would depend also on eye observations, I have preferred to give here the values commencing only with 1849, the beginning of the available photographic record. One portion is, indeed, new; the monthly means 1849 to 1868, as corrected for omitted days, not having been before published.

It may be useful here to indicate the changes that from time to time have been made in the position of the revolving stand, on which the thermometers for eye observation are placed, and to the dry bulb thermometer of which the photographic indications are reduced. It was first brought into use in March of the year 1841 (the observations for the few previous months having been made with the thermometer suspended in a temporary manner), and was originally set up in the north-east re-entering angle of the Magnetic Observatory, about 6 ft. from the walls of the building; in July of the year 1846 it was moved to a position 23ft. south of the southern arm of the Magnetic Observatory, and in 1868 was shifted to a position 12 ft. further south. In the summer of the year 1878 some minor repairs and alterations of the stand were made, and in September of the same year a horizontal circular board 3 ft. in diameter was fixed to the post carrying the thermometer frame, in a position below the frame, at a height of 2 ft. 6 in. above the ground.

It will be seen by the accompanying table that the mean annual temperature deviates from the general mean of the 40 years, by more than 1° in excess, in nine of the years of the series, the only deviation above 2° being +2°·5 in 1868, a memorable year, in which, in more than half of the months of the year, the temperature was considerably above the average. The annual temperature deviates from the general mean more than 1° in defect, in six of the years, the deviations above 2° being —2°·3, —2°·0, and —3°·2 in 1855, 1860, and 1879 respectively, due in 1855 mostly to the extreme cold of the early part of the year, in 1860 to the remarkably cold summer, and in 1879 to extreme cold in spring and early summer and at the beginning and end of the year. The mean annual departure from the average, irrespective of sign, is 0°·88. The preponderance of cold in the last 10 years, 1879 to 1888, I have before pointed out:[1] only in two years out of the ten is the annual temperature above the general average: a long sustained depression, to be followed, no doubt, in due course by a series of warm years, although the two following years 1889 and 1890 have proved to be also cold years. It would be of great interest to make out whether the effect is a local one, and if so to what extent, and whether this part of the world only has suffered in this way.

[1] On the Variation of the Temperature of the Air in England during the period 1849 to 1888. *Quarterly Journal Royal Meteorological Society*, Vol. XV. p. 228

MONTHLY MEAN TEMPERATURE OF THE AIR AT THE ROYAL OBSERVATORY, GREENWICH, AS DEDUCED FROM THE PHOTOGRAPHIC RECORDS, 1849–1888.

The means depend on 24 daily values, reduced to the reading of the dry bulb thermometer of the revolving stand. No correction has been applied for elevation, 160 feet above sea level.

Year.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Yearly Mean.	Excess above Average.
	°	°	°	°	°	°	°	°	°	°	°	°	°	°
1849	40·8	43·1	42·9	44·5	54·8	59·4	62·2	62·7	58·5	51·3	44·1	39·2	50·3	+0·8
1850	34·1	44·5	39·9	49·3	51·6	61·2	62·2	60·8	56·2	46·7	46·4	40·4	49·4	—0·1
1851	43·0	40·0	42·7	45·5	51·7	59·7	60·3	62·6	56·2	52·5	37·7	40·6	49·4	—0·1
1852	41·9	40·7	40·6	45·4	52·1	56·9	67·0	62·3	56·8	47·8	49·0	47·6	50·7	+1·2
1853	42·6	33·2	38·2	46·0	52·5	59·0	61·0	60·1	55·4	51·3	42·2	34·0	48·0	—1·5
1854	39·3	39·4	43·6	48·6	51·2	56·5	61·0	61·1	57·9	49·5	40·6	41·2	49·2	—0·3
1855	34·9	29·2	37·8	45·9	49·3	57·7	62·6	62·4	57·3	51·5	41·6	36·2	47·2	—2·3
1856	39·2	42·1	39·1	47·5	49·9	59·7	61·6	63·7	55·2	52·0	41·0	40·2	49·3	—0·2
1857	36·8	38·9	41·9	46·3	54·3	62·5	65·1	65·7	59·9	53·2	46·0	45·1	51·3	+1·8
1858	37·6	34·9	41·5	46·8	52·2	65·7	61·4	62·3	60·4	51·2	39·5	41·1	49·6	+0·1
1859	40·5	43·4	46·8	47·5	53·5	62·3	68·9	63·9	57·0	51·4	42·1	36·7	51·2	+1·7
1860	40·0	35·7	41·5	43·3	54·6	55·7	58·3	58·2	53·7	51·2	41·0	36·4	47·5	—2·0
1861	34·0	42·2	44·1	44·9	52·7	59·9	61·5	63·5	57·3	55·2	41·0	41·0	49·8	+0·3
1862	39·3	41·3	43·3	49·2	55·9	57·1	59·6	59·6	57·7	52·5	39·8	43·7	49·9	+0·4
1863	42·2	42·2	43·9	49·6	52·3	58·8	61·4	62·3	53·9	51·9	45·9	43·6	50·7	+1·2
1864	36·6	36·0	41·5	48·8	54·6	58·3	62·3	60·2	57·1	50·9	42·3	38·6	48·9	—0·6
1865	36·5	37·0	36·7	52·9	56·9	61·7	64·6	60·4	63·8	51·3	45·2	42·9	50·8	+1·3
1866	43·1	40·9	40·8	48·6	50·8	61·8	61·9	59·7	56·6	51·6	44·7	43·1	50·3	+0·8
1867	34·6	45·1	38·0	49·9	54·0	59·2	60·1	62·5	57·8	49·1	41·5	37·7	49·1	—0·4
1868	37·6	43·5	44·5	48·7	58·0	63·2	68·1	63·9	60·4	48·2	41·8	46·1	52·0	+2·5
1869	41·4	45·6	37·9	50·9	51·1	56·2	64·8	60·9	59·1	49·3	43·4	37·9	49·9	+0·4
1870	38·5	36·3	40·1	49·2	54·1	62·2	66·0	61·3	56·0	50·4	41·8	33·7	49·1	—0·4
1871	33·4	42·6	45·0	48·2	52·4	55·5	62·0	64·9	57·7	49·6	37·4	38·4	48·9	—0·6
1872	41·5	44·8	44·7	48·8	51·5	60·0	65·5	60·9	57·7	48·3	45·5	42·9	51·0	+1·5
1873	42·3	34·7	42·1	46·3	51·2	59·4	64·0	62·9	54·9	48·3	44·5	40·7	49·3	—0·2
1874	41·9	39·0	44·1	50·5	51·0	58·8	64·9	60·8	58·2	52·2	42·2	33·3	49·7	+0·2
1875	43·6	35·5	40·9	47·0	55·6	60·0	59·9	63·6	60·8	49·3	42·7	38·6	49·8	+0·3
1876	37·3	41·3	41·6	48·0	50·1	59·6	66·7	64·2	56·3	53·6	44·2	44·2	50·6	+1·1
1877	42·9	44·0	41·0	46·1	49·4	62·3	61·5	62·2	53·3	49·4	46·0	41·0	49·9	+0·4
1878	40·4	42·3	42·3	48·0	55·1	60·2	63·2	62·5	56·9	51·5	39·8	33·7	49·7	+0·2
1879	31·8	38·3	41·2	43·5	48·6	57·0	58·2	60·2	56·3	49·3	38·5	32·5	46·3	—3·2
1880	33·3	42·1	44·2	47·2	52·6	57·5	61·6	62·8	59·7	46·4	42·8	43·3	49·5	0·0
1881	31·7	38·0	42·6	45·8	54·0	58·6	65·5	59·2	55·7	45·4	49·0	39·9	48·8	—0·7
1882	40·5	42·0	46·2	48·0	54·5	56·7	60·3	59·9	54·6	51·0	43·8	40·2	49·8	+0·3
1883	41·4	42·9	36·3	47·0	53·1	58·9	59·8	62·2	56·9	50·7	43·7	40·5	49·4	—0·1
1884	43·9	42·1	44·4	45·3	54·2	58·1	63·2	65·1	59·4	49·2	42·6	41·2	50·7	+1·2
1885	36·6	43·9	40·3	47·6	49·8	59·6	63·6	58·6	55·4	46·5	43·5	39·0	48·7	—0·8
1886	36·3	33·7	39·8	46·6	53·3	57·7	63·1	62·3	59·1	53·3	44·4	36·6	48·8	—0·7
1887	35·8	38·9	37·9	44·2	50·1	61·0	66·5	62·5	54·4	45·2	40·8	38·0	47·9	—1·6
1888	37·9	35·3	38·3	43·5	53·0	58·3	58·0	59·2	55·9	46·0	47·2	40·8	47·8	—1·7
Means 1849–1858	39·0	38·6	40·8	46·6	52·0	59·8	62·4	62·4	57·4	50·7	42·8	40·6	49·4	—0·1
Means 1859–1868	38·4	40·7	42·1	48·3	54·3	59·8	62·7	61·4	57·5	51·3	42·5	41·0	50·0	+0·5
Means 1869–1878	40·3	40·6	42·0	48·3	52·2	59·4	63·8	62·4	57·1	50·2	42·7	38·4	49·8	+0·3
Means 1879–1888	36·9	39·7	41·1	45·9	52·3	58·3	62·0	61·2	56·7	48·3	43·6	39·2	48·8	—0·7
Means 1849–1888	38·7	39·9	41·5	47·3	52·7	59·3	62·7	61·9	57·2	50·1	42·9	39·8	49·5	..

Discussion has sometimes arisen as to the most desirable period to employ for the formation of temperature averages. It has been urged that periods of 50 years or more are too long, and that it is better to use periods of 10 or 20 years only. Periods of 10 years, however, would appear in this climate to be, from what has been remarked in the last paragraph, much too short. At the foot of the table of temperatures, monthly means have been added for each 10 years, and the differences of the means in the several months are as follows :—

	°		°		°
January	3·4	May	2·3	September	0·8
February	2·1	June	1·5	October	3·0
March	1·3	July	1·8	November	1·1
April	2·4	August	1·2	December	2·6

The means, on the whole, evidently vary to the greatest extent in winter. Even employing means for 20 years, that for the first 20 years would differ from that for the last 20 years by nearly 2° in October, and by exactly 2° in December.

It has sometimes been imagined that the temperatures determined at Greenwich Observatory may be so influenced by the growth of London that they cannot be accepted as truly indicating the general variations of temperature. It does not appear, however, that this condition has been yet reached. In the paper on the variation of the temperature of the air in England, already referred to, I collected the results of the observations of temperature, contained in the *Quarterly Return* of the Registrar General, for the period 1849 to 1888, and gave means for groups of stations as arranged according to latitude; one set of means applying to stations situated between latitudes 51° and 52,° another to stations between 52° and 53°, and another to stations between 53° and 54°. It happens that the period covered by the numbers there given is precisely that of the present table, and Greenwich being situated as regards latitude in the middle of the 51°-52° zone, it is interesting to compare the changes indicated generally in that zone with the changes shown at Greenwich. Summer is taken to include the months from April to September, and winter those for the remaining portion of the year.

Period.	Winter. Stations in zone 51°-52°.	Winter. Royal Observatory.	Summer. Stations in zone 51°-52°.	Summer. Royal Observatory.	The Year. Stations in zone 51°-52°.	The Year. Royal Observatory.
	°	°	°	°	°	°
1849-1868	42·26	42·89	56·22	57·05	49·24	49·72
1869-1888	41·91	41·93	55·71	56·64	48·81	49·29
Difference	−0·35	−0·46	−0·51	−0·41	−0·43	−0·43

The decrease shown by these 20 years' means is somewhat greater in winter and less in summer at the Royal Observatory than generally in the zone 51°-52°. For the complete year the differences are identical. This is hardly surprising. The Royal Observatory is situated in the middle of Greenwich Park, within which buildings cannot be erected. The park abuts mainly on

the River Thames to the north, and is bounded on the south by the large open space of Blackheath. The Observatory thus occupies a very open position, and one not likely in the immediate future to be further encroached upon.

There is another matter on which I would add a few remarks. The corrections for diurnal range, given by Mr. Glaisher in his paper in the *Philosophical Transactions* before referred to, differ in some respects from those found from the Greenwich twenty years' reductions. In explanation of these differences various suggestions have been made; one that they may be due to the photographic thermometer, on which the 20 years' corrections depend, being sluggish, as compared with the thermometer of the revolving stand, on the eye observations of which the corrections determined by Mr. Glaisher depend; another suggestion is that the differences may be owing to the different manner of exposure. I do not think that the photographic thermometer can be said to be really sluggish.[1] Length of bulb does not imply sluggishness if the diameter be not excessive and other proportions appropriate. Very sensitive thermometers would be for such a purpose unsuitable. If the causes suggested have any real influence it is only in a minor degree. The true explanation of the differences between the two sets of corrections is due, in my opinion, mainly to the circumstance that Mr. Glaisher's corrections depend on five years' observations only, whilst the later corrections depend on the records of twenty years. It is not that the results essentially differ even as they stand, but rather that, comparing one month with another, there are irregularities which five years' observations (all that were at the time available) are not sufficient to eliminate. That this is so is easily seen. If the 24 hourly deviations in each of the 12 months be all summed together, without regard to sign, the sum for Mr. Glaisher's corrections is 960°·9, and for the 20 years' corrections 963°·2, indicating (dividing by $24 \times 12 = 288$) mean corrections of 3°·34 in both cases. The point is that any systematic difference in the magnitude of the diurnal range would tell greatly in the sums of the hourly deviations just given. Or, dividing the year, we have for summer (April to September), sum of Mr. Glaisher's corrections 675°·0, of the 20 years' corrections 670°·9, indicating (dividing by 144) mean corrections of 4°·69 and 4°·66 respectively. For winter (including the remaining months), sum of Mr. Glaisher's corrections 285°·9, of the 20 years' corrections 292°·3, indicating mean corrections respectively of 1°·99 and 2°·03. On the whole there is thus agreement, the differences in individual months arising evidently from unavoidable irregularity in Mr. Glaisher's five years' series, affecting in greatest degree the months of April, June, and July.

I am aware that it has been pointed out that there are anomalies in Mr. Glaisher's corrections in some months of the year. The sum of the positive corrections in each month should balance the sum of the negative corrections, but in August, September, and October, the positive values are in excess. If,

[1] Some of the photographic records were exhibited showing the ready action of the photographic thermometer in cases of sudden depression of temperature during squalls, of which the anemometer record gave the period.

however, the 24 hourly values in each month correctly represent the amplitude of the observed temperature curve, the comparison with the newer 20 years' corrections will not be practically affected, and would not at all be affected if the positive and negative corrections in each month were equal in number, 12 of each.

It was mentioned in an earlier part of this paper that the corrections for reducing the mean of the readings of the maximum and minimum thermometers to the true mean, found by comparing, for the period 1849-1868, the maximum and minimum mean in each month, with the mean of 24 hourly values, had not been published. The corrections required by the maximum and minimum mean were found to be as follows :—

	°		°		°
January	+ 0·1	May	— 0·7	September	— 1·1
February	— 0·4	June	— 0·7	October	— 0·6
March	— 0·7	July	— 0·9	November	— 0·1
April	— 0·8	August	— 1·2	December	+ 0·3

Unlike the corrections for diurnal range, these corrections sensibly differ in amount from those found by Mr. Glaisher, and given in his paper in the *Philosophical Transactions* for 1848, but a certain proportion of the difference is due to the circumstance that the readings of the maximum and minimum thermometers, on which Mr. Glaisher's corrections are founded, were taken at 10 a.m., thus causing the maximum and minimum means used by him (practically climatological day means) to be relatively higher than those referring to the civil day, to which the above corrections apply. (See *Quart. Jour. R. Met. Soc.* Vol. XVI. p. 213.)

I should like, in conclusion, to give some indication of the degree of accuracy attainable in the calculation of mean daily temperatures by the use of corrections applied to a few observations daily. The mean daily temperatures given, since the year 1878, in the report communicated weekly to the Registrar General, are found by combining the mean of the maximum and minimum readings, corrected by the numbers above given, with the mean of the ordinary eye observations (usually four) corrected for diurnal inequality, by corrections depending on the twenty years' reductions, varying both sets of corrections through each month as necessary. The temperatures have to be calculated for the Registrar General's weekly report in this way because, having to be got out so quickly, there is not sufficient time to tabulate the photographs. But a good approximation, indeed a very fair value of mean temperature, is thus found, as may be seen by comparing the daily values given in the Registrar General's weekly report in any year since 1878 with those afterwards determined from 24 hourly photographic values, and inserted in the Greenwich volume. Taking the year 1888, the last appearing in the table in this paper, and making comparison for the months of January, April, July, and October, we find that the mean daily temperature given in the Registrar General's report deviates from the photographic temperature, by more than 1°, only three times in January, twice in April, once in July,

and four times in October, the greatest deviation on any day in these months being respectively 1°·8, 1°·4, 1°·4, and 2°·6. The average deviation taken without regard to sign is respectively 0°·4, 0°·5, 0°·6, and 0°·6. The differences are evidently of accidental character, as is shown by the agreement of the monthly means. Thus the monthly means of the daily values in the Registrar General's report for January, April, July, and October 1888, are respectively 37°·8, 43°·4, 57°·9, and 46°·0, the monthly means of the values afterwards given in the Greenwich volume being respectively 37°·9, 43°·5, 58°·0, and 46°·0, which are practically the same. And in the whole eleven years, 1878 to 1888, there is no instance of a deviation greater than 0·°4 between the corresponding monthly means. I think it will be seen from this comparison, that the values, given in advance in the Registrar General's report, are fairly representative and if required may be taken as representative of those, afterwards found from the photographs, which appear in the annual Greenwich volume. I do not pretend to say that the corrections for Greenwich would give equally satisfactory results for other places, but it is probable that they could be usefully employed for the comparison of results for different places at which the hours of observation were not the same.

On the Comparison of Thermometrical Observations made in a Stevenson Screen with Corresponding Observations made on the Revolving Stand at the Royal Observatory, Greenwich.

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The use of the Stevenson screen for exposure of thermometers for determination of air temperature having become so general in England during late years, the Royal Meteorological Society, in the year 1883, appointed a Committee, of which I was myself a member, to consider the best pattern of screen for use by observers in connection with the Society. Their report, in which the adopted form of screen is described, will be found in the *Quarterly Journal*, Vol. X., page 92. Afterwards, in the year 1886, on my suggestion, a Stevenson screen of the pattern recommended was set up at the Royal Observatory, Greenwich, adjacent to the open revolving stand, commonly known as the "Glaisher Stand," for the purpose of comparing the indications of thermometers placed in the screen with those of the corresponding thermometers of the revolving stand. A description of the revolving stand will be found in the Introduction to the Greenwich annual volume. The screen

contains a maximum thermometer, a minimum thermometer, a dry bulb thermometer, and a wet bulb thermometer, and since the beginning of the year 1887 observations of these thermometers have been regularly made at the times at which the revolving stand thermometers were read, that is to say, the daily maximum and minimum have been observed, and readings of the dry bulb and wet bulb thermometers taken at 9 a.m., noon, 3 p.m., and 9 p.m., excepting that readings of the screen thermometers have not been taken on Sundays, but since the question is one of differences, this does not signify. The results at present available are those for the years 1887, 1888, and 1889; they are given in complete detail in the Greenwich annual volumes, but it seems desirable now to collect them in order to show what general conclusions may be drawn therefrom. The mean differences for the same month in different years are in such close agreement that it seems quite unnecessary to give in this paper the separate monthly differences, but only the mean values for each month as found from the observations made during the three years mentioned. These are contained in Table I. It should be explained, as respects the observations made at stated hours, that the order of observing the screen and revolving stand thermometers was reversed on alternate days, in order to avoid the introduction of any constant difference due to diurnal change.

Considering the numbers of Table I. it will be seen that the maximum readings in the Stevenson screen are lower than those of the revolving stand in all months of the year, not much lower in winter, but considerably lower during the summer months, also that the minimum readings in the screen are distinctly higher than those of the revolving stand throughout the year, the difference being somewhat greater during the summer and autumn than at other times. The mean of the maximum and minimum readings in the screen differs little in the winter months from that of the revolving stand mean, but is lower in other months of the year, the difference being greatest in the summer months, depending on the greater difference of the maximum readings at that period of the year.

The readings of the dry bulb thermometers of the Stevenson screen and revolving stand, as taken at definite hours, are in much closer agreement than are those of the self-registering thermometers; the screen readings being at noon and at 3 p.m., even in summer, only a few tenths of a degree below those of the revolving stand. This is in striking contrast with the larger differences existing in summer, between the readings of the maximum thermometers of the screen and revolving stand. In the latter part of the year the screen readings at 3 p.m. are higher than those of the revolving stand, the values for the separate months in each of the three years being in close agreement in this respect. At 9 a.m. the differences are in most months small; at 9 p.m. the screen readings are higher throughout the year.

The differences between the readings of the Stevenson screen and revolving stand wet bulb thermometers, at the stated hours of observation, are in close accord with the differences between the corresponding dry bulb readings, being usually of the same sign and somewhat less in amount; indicating that,

TABLE I.

Month.	Excess of Stevenson Screen Readings over Readings on the Revolving Stand, from observations made during the years 1887, 1888 and 1889. Self-Registering Thermometers.			Dry Bulb Thermometer.				Wet Bulb Thermometer.			
	Maximum.	Minimum.	Mean of Max. and Min.	9 a.m.	Noon.	3 p.m.	9 p.m.	9 a.m.	Noon.	3 p.m.	9 p.m.
	°	°	°	°	°	°	°	°	°	°	°
January ..	−0·30	+0·27	−0·02	+0·03	−0·10	−0·03	+0·13	−0·03	−0·03	+0·03	+0·10
February ..	−0·43	+0·30	−0·06	−0·03	−0·17	−0·07	+0·10	0·00	−0·07	+0·03	+0·13
March	−0·87	+0·37	−0·25	−0·10	−0·23	−0·17	+0·10	−0·17	−0·20	−0·10	+0·07
April	−1·63	+0·37	−0·63	−0·23	−0·30	−0·20	+0·20	−0·10	−0·13	−0·07	+0·27
May	−1·77	+0·37	−0·70	−0·20	−0·47	−0·37	+0·27	−0·13	−0·27	−0·13	+0·23
June	−2·03	+0·43	−0·80	−0·23	−0·50	−0·37	+0·17	−0.13	−0·30	−0·17	+0·07
July	−2·23	+0·47	−0·88	−0·27	−0·40	−0·40	+0·17	−0·20	−0·17	−0·13	+0·10
August	−1·97	+0·53	−0·72	−0·07	−0·27	−0·10	+0·23	−0·13	−0·20	−0·13	+0·17
September..	−1·17	+0·57	−0·30	0·00	+0·10	+0·03	+0·20	−0·07	+0·03	+0·03	+0·13
October	−0·87	+0·57	−0·15	−0·03	+0·10	+0·10	+0·23	0·00	0·00	+0·07	+0·20
November ..	−0·47	+0·37	−0·05	0·00	0·00	+0·13	+0·13	0·00	−0·07	+0·10	+0·13
December ..	−0·13	+0·27	+0·07	0·00	−0·07	+0·17	+0·17	−0·03	−0·07	+0·13	+0·13
Summer Mean, April to September	−1·80	+0·46	−0·67	−0·17	−0·31	−0·24	+0·21	−0·13	−0·17	−0·10	+0·16
Winter Mean, October to March	−0·51	+0·36	−0·08	−0·02	−0·08	+0·02	+0·14	−0·04	−0·07	+0·04	+0·13
Yearly Mean	−1·16	+0·41	−0·37	−0·09	−0·19	−0·11	+0·18	−0·08	−0·12	−0·03	+0·14

on the whole, the revolving stand dry and wet bulb readings and the screen dry and wet bulb readings would independently give much the same values of dew point and of humidity.

If for the dry bulb and wet bulb thermometers we take the mean of the differences of the screen and revolving stand temperatures at 9 a.m., noon, and 3 p.m. to represent the day condition, and the 9 p.m. difference to indicate the night condition, we obtain the numbers given in Table II.

Briefly, then, we have these results. The maximum temperature in the screen is lower than that of the revolving stand, in summer much lower, and the minimum temperature is higher; whilst the readings of the screen and revolving stand dry bulbs, and of the screen and revolving stand wet bulbs, as taken at stated hours, show differences of a very much less marked character; so much so, that any ordinary combination of observations of the screen dry bulb would give a mean temperature practically similar to a like combination of observations of the revolving stand dry bulb.

It has been affirmed that the readings on the revolving stand by day in summer are unduly influenced by radiation from the ground and from th

TABLE II.

Month.	Excess of Stevenson Screen Readings over Readings on the Revolving Stand, from observations made during the years 1887, 1888 and 1889. Dry Bulb Thermometer. By Day.	Dry Bulb Thermometer. By Night.	Dry Bulb Thermometer. Mean.	Wet Bulb Thermometer. By Day.	Wet Bulb Thermometer. By Night.	Wet Bulb Thermometer. Mean.
	°	°	°	°	°	°
January	−0·03	+0·13	+0·05	−0·01	+0·10	+0·05
February	−0·09	+0·10	0·00	−0·01	+0·13	+0·06
March	−0·17	+0·10	−0·03	−0·16	+0·07	−0·04
April	−0·24	+0·20	−0·02	−0·10	+0·27	+0·08
May	−0·35	+0·27	−0·04	−0·18	+0·23	+0·03
June	−0·37	+0·17	−0·10	−0·20	+0·07	−0·06
July	−0·36	+0·17	−0·09	−0·17	+0·10	−0·03
August	−0·15	+0·23	+0·04	−0·15	+0·17	+0·01
September....	+0·04	+0·20	+0·12	0·00	+0·13	+0·06
October	+0·06	+0·23	+0·14	+0·02	+0·20	+0·11
November	+0·04	+0·13	+0·09	+0·01	+0·13	+0·07
December	+0·03	+0·17	+0·10	+0·01	+0·13	+0·07
Summer Mean, April to Sept.	−0·24	+0·21	−0·02	−0·13	+0·16	+0·01
Winter Mean, Oct. to March	−0·03	+0·14	+0·06	−0·02	+0·13	+0·05
Yearly Mean	−0·13	+0·18	+0·02	−0·08	+0·14	+0·03

white buildings in the meteorological court, and the comparison of the revolving stand maxima with the Stevenson screen maxima seems to give support to such idea. But if this be the explanation of the higher revolving stand maxima, the dry bulb readings of the revolving stand and screen at noon and at 3 p.m. should show similar differences, instead of differences which are in every way so very much smaller, and which, indeed, in some months are persistently reversed in direction, the screen readings being the higher. There is nothing in the positions which the various thermometers occupy on the revolving stand which should cause anomalies. The stand is 4 ft. 6 ins. wide, the bulbs of the different thermometers are all placed towards the centre of the stand, which is kept with its inclined side always towards the sun, whether the sky be clear or cloudy, being turned through a certain angle at stated times every day.

We have now, however, some direct evidence bearing upon the question of radiation. As regards radiation from the ground, it may be mentioned that it was because of a suggestion that ground radiation might affect the readings of the thermometers on the revolving stand that in the year 1878 a horizontal circular board, 3 ft. in diameter, was fixed on the post carrying the thermometer frame, in a position below the frame, at a height of 2 ft. 6 ins. above the ground, with the object of affording protection to the thermometers in this respect. In the summer of the year 1886, some experiments were made to ascertain whether the removal of the board produced any difference

of reading. On four days of high temperature and bright sunshine, observations were made of the dry bulb and wet bulb thermometers, at short intervals, with the circular board alternately removed and attached, the details of which observations are given at the end of the Introduction to the *Greenwich Magnetical and Meteorological Observations* for the year 1887. All the observations made are published, and the following are the results :—

1886.		Duration of Experiment.	Number of Comparisons.	Mean reading of dry bulb thermometer on revolving stand with circular board removed.	attached.	Excess with circular board removed.
		h. m.		°	°	°
August	21	2.40	5	71·5	71·9	—0·4
,,	28	3.30	10	71·0	70·9	+0·1
,,	30	5.30	16	83·5	83·9	—0·4
,,	31	3.50	11	85·7	85·6	+0·1
		Means		77·92	78·07	—0·15

The concluded mean reading of the dry bulb thermometer with the circular board removed is thus slightly less than with the board attached. In the case of the wet bulb thermometer, the corresponding differences were :—0°·2, +0°·1, 0°·0, and +0°·1, the mean difference being 0°·00. This indicates that the removal of the circular board produces no real difference in the readings.

As respects radiation from the surrounding white buildings, the erection of the Stevenson screen afforded an excellent opportunity of testing this particular question. The screen is placed a little to the east of the revolving stand, both occupying positions distant somewhat more than 30 ft. south of the Magnet House, which building the Stevenson screen faces; so that, on opening the front vertical door, the screen thermometers become exposed to the direct influence of any radiation from the building equally with the thermometers on the revolving stand; an influence which, on closing the screen door, becomes, for the screen thermometers, completely shut off. On four days of high temperature and bright sunshine in the summer of the year 1887 observations were made of the dry bulb and wet bulb thermometers, at short intervals, with the door of the screen alternately open and shut. All details are given in the Greenwich volume for 1887, and all the observations made are published.

1887.		Duration of Experiment.	Number of Comparisons.	Mean reading of the dry bulb thermometer of the Stevenson Screen with the door of the screen open.	shut.	Excess with door open
		h. m.		°	°	°
July	4	3.15	6	87·1	87·5	—0·4
August	3	1.10	2	69·7	69·5	+0·2
,,	4	1.40	3	70·9	71·3	—0 4
,,	6	3.40	7	83·1	82·9	+0·2
		Means		77·70	77·80	—0·10

The concluded mean is thus, in an insignificant degree, lower with the door open than with the door shut. In the case of the wet bulb thermometer the corresponding differences were —0°·2, 0°·0, 0°·0, and —0°·3, the mean difference being – 0°·12. Corresponding readings of the dry bulb thermometer of the revolving stand were also taken, the mean being 78°·75, or 1°·05 higher than that of the screen dry bulb 77°·70, no very remarkable difference at a temperature so extreme.

Further, when the new thermograph was set up on the ground south of the meteorological court, known as the south ground, the thermometer bulbs were carefully protected from all possible radiation effects by two boards on the north side and two on the south side, an east-end board, a west-end board, and one horizontal board below, but with free circulation of air between all the boards. On five days of high temperature and bright sunshine during the summer of the year 1886 the north and south boards were alternately removed and attached at short intervals, and the photographic record of the dry bulb thermometer independently tabulated by two different observers, whose tabulations were practically identical. All details are to be found in the Greenwich volume for 1887, and, as before, no results have been omitted.

1886.		Duration of Experiment.	Number of Comparisons.	Mean reading of the dry bulb thermometer of the new thermograph for intervals during which the north and south boards were attached.	were removed.	Excess with boards removed.
		h.m.		°	°	°
July	5	2.20	3	78·7	78·8	+0·1
,,	7	2.20	3	81·9	81·7	—0·2
,,	20	4.20	6	70·7	70·7	0·0
,,	21	5. 0	7	80·9	81·1	+0·2
Sept.	1	5.15	10	80·5	80·6	+0·1
		Means		78·54	78·58	+0·04

With the boards removed, the thermometer was open to any radiation from the surrounding wooden buildings and fences. Practically the removal of the boards produced no effect, and, indeed, before the commencement of regular work with the new thermograph on January 1st, 1887, one north board and both south boards were permanently removed.

The experiments made with the circular board of the revolving stand show that its removal produced no real difference in the thermometer readings. The experiments made with the Stevenson screen show that the screen readings are practically similar both with the door of the screen open and shut, and in the experiments with the thermograph the removal of the protecting boards produced no real change of reading. Further, these experiments receive corroboration from the near agreement of the revolving stand readings with the screen readings at the stated hours of observation. In such widely

different conditions of exposure, indeed, the differences really observed (see second and third divisions of Table I.) are such as may reasonably be supposed to be in part due to contraction of the range in the screen, acting to depress the screen readings by day and raise them by night, and so far the revolving stand thermometers do not appear to be influenced by radiation in the way that has been alleged. It would seem that, for the circumstance that the maximum readings on the revolving stand are so much higher in summer than those of the screen, as compared with the lesser differences between the readings taken at stated hours, some other explanation must now be sought. It is to be remembered that on a fine day in summer the temperature is frequently subject to fluctuations of brief duration. The maximum is, of course, the highest point touched, no matter for how short a time such temperature is maintained, and the screen maximum thermometer may be less sensitive to such changes than is the more completely exposed revolving stand maximum. The readings taken at stated times, on the other hand, are as likely to fall at the base as at the crest of such fluctuations. But even in the absence of any sufficient explanation of this apparent discordance, the observed facts, considered as a whole, do not appear to at all warrant the conclusion that, because the revolving stand maxima are higher than the screen maxima, they are on that account necessarily wrong.

It has been suggested that, after having carried on for a few years comparisons of the revolving stand and Stevenson screen thermometers, the use of the revolving stand should be discontinued. That would rather be to replace an imperfect stand by an imperfect screen. Each may have its faults. But it seems every way better to let stand and screen be both at present maintained, especially when there is a willingness to carry on duplicate observations, rather than to contemplate the immediate interruption of a long series of observations made in one definite way, and commenced long before the Stevenson screen was thought of.

The mean daily and monthly values of air temperature, as given in the annual volume have, since the year 1877, been formed from hourly measures of the photographs reduced to the dry bulb of the revolving stand. Table II. of this paper shows that values so obtained are practically such as would be found were the photographic values reduced to the screen dry bulb, instead of to the revolving stand dry bulb, that is to say, the concluded temperatures would differ only in an insignificant degree. Such being the case, it is a further argument for retaining at present the existing system, rather than replace the revolving stand by another form, which would introduce into mean values a small but doubtful correction, as regards absolute truth, but yet one that, in making any fundamental change, should properly be taken account of, although otherwise scarcely worth consideration.

Finally, it should be mentioned that all thermometers are carefully compared every year with the standard thermometer No. 515, a thermometer kindly supplied in the year 1875 to the Royal Observatory by the Kew Committee of the Royal Society, and that all corrections for index error are rigorously applied.

ADDENDUM.

It has occurred to me that it might be interesting to add to the preceding paper a comparison of the observations of the thermometers placed on the roof of the Magnet House with the corresponding observations of the thermometers of the revolving stand. The roof thermometers are mounted in a louvre boarded shed or screen, so constructed as to give free circulation of air, with protection from radiation. It is open towards the north. The thermometers are a maximum thermometer, a minimum thermometer, and a dry bulb thermometer, but no wet bulb. The bulbs of the thermometers are 4 ft. above the platform and 20 ft. above the ground. As with the Stevenson screen thermometers, readings have not been taken on Sundays. The observations were commenced at the beginning of the year 1886, and the results for four years are now available.

Month.	Excess of Roof Thermometer Readings over Readings on the Revolving Stand from observations made during the years 1886, 1887, 1888, and 1889.						
	Self-Registering Thermometers.			Dry Bulb Thermometer.			
	Maximum.	Minimum.	Mean of Max. and Min.	9 a.m.	Noon.	3 p.m.	9 p.m.
	°	°	°	°	°	°	°
January	+0·30	+0·15	+0·23	+0·37	+0·22	+0·35	+0·40
February	—0·23	+0·10	—0·07	+0·23	—0·12	+0·12	+0·30
March	—0·50	+0·13	—0·18	+0·10	—0·30	+0·02	+0·33
April	—1·25	+0·20	—0·53	—0·23	—0·52	—0·35	+0·22
May	—1·27	+0·25	—0·51	—0·20	—0·70	—0·38	+0·33
June	—1·63	+0·28	—0·67	—0·35	—0·95	—0·50	+0·12
July	—1·77	+0·32	—0·73	—0·45	—0·78	—0·37	+0·20
August	—0·53	+0·28	—0·62	—0·17	—0·42	—0·15	+0·43
September	—0·90	+0·32	—0·29	—0·15	—0·20	+0·02	+0·45
October	—0·47	+0·33	—0·07	+0·05	—0·15	+0·23	+0·42
November	—0·10	+0·35	+0·12	+0·40	+0·12	+0·30	+0·35
December	+0·33	+0·30	+0·31	+0·40	+0·30	+0·45	+0·48
Summer Mean—April to Sept.	—1·39	+0·27	—0·56	—0·26	—0·59	—0·29	+0·29
Winter Mean—October to March	—0·11	+0·23	+0·06	+0·26	+0·01	+0·25	+0·38
Yearly Mean	—0·75	+0·25	—0·25	0·00	—0·29	—0·02	+0·34

DISCUSSION.

Mr. MAWLEY said that he had made a comparison of the various Greenwich mean temperatures as obtained by Mr. Glaisher, Mr. Eaton, and Mr. Ellis, in the cases of years where the records employed overlapped, and could find very little agreement between them. He then quoted some figures showing the divergencies of the various means. He thought it would have been better to have kept from the first to the simple means as deduced from the daily maximum and minimum readings. Regarding the comparison between the tempera-

tures registered on the revolving stand and in the Stevenson screen, Mr. Ellis's figures showed greater differences between the two forms of exposure than he (Mr. Mawley) had obtained from six years' observations made with similar screens at Addiscombe. His experience in observing with different screens had taught him that a great deal depended upon whether there was a good lawn under the thermometer screen. He could not understand why during the summer months the mean differences between the temperatures on the two screens at Greenwich should come out about four times as great in the case of the maxima as in that of the 8 p.m. readings.

Mr. Symons agreed with Mr. Ellis that it would be a great pity to give up the observations made on the revolving stand in favour of those made in the Stevenson screen, and he sincerely hoped that the old form of stand would continue in use, as it had now done service at Greenwich for so many years; and he hoped that the authorities would be able to arrange that in future the readings of the thermometers in the Stevenson screen should be taken on Sundays, so that there would be available (1) a record strictly comparable with that of past years, and (2) a record strictly comparable with those from the inspected stations of the Royal Meteorological Society. He considered that meteorology at the Royal Observatory was badly treated by the authorities, and he thought it would be an advantage if a large part of the spectroscopic and astronomical work were carried on at a more suitable locality in the country, so that better provision could be made for the meteorological department.

Mr. C. Harding said that the means given by Mr. Ellis were exceedingly valuable, and it was a great gain that correction had been made for the gaps which from various causes occurred in the series of observations. He had always looked upon the Greenwich volume containing the reduced temperature observations for the 20 years 1849-68 as a splendid piece of work, and a work of high scientific value which supplied a great need for the ordinary inquirer. He had shared the opinion expressed by the Astronomer Royal in the text which accompanies the Tables "that the whole work may be considered as a model of accuracy on a very large scale." He was greatly surprised to notice the large differences which were shown between the values in the Greenwich volume and Mr. Ellis's figures, differences which from their magnitude greatly lessen the usefulness of the Greenwich reductions. He had tabulated and taken the averages of the daily maximum and minimum readings at Greenwich since 1840, and on comparing the means thus obtained with Mr. Ellis's figures, he found a very good agreement. He quoted certain differences which occur between the values in the Greenwich volume for 20 years, and those given now by Mr. Ellis. In the volume for 20 years the January and February means for 1849 are respectively 42°·7 and 42°·3, whereas, according to Mr. Ellis, they should be 40°·8 and 43°·1, so that instead of February being colder than January by 0°·4 it is really warmer by 2°·3. According to the Greenwich volume December 1860 is 3°·5 warmer than December 1859, but Mr. Ellis's values show it to be 0°·3 colder, and this sort of difference occurs very frequently where opportunity is afforded for comparison. It is these differences which, being known to exist, will greatly lessen the value of the Greenwich volume. No attempt having been made to correct for the absence of observations throughout the series of the Greenwich observations also vitiates very greatly other parts of the work—for example, in May 1868 the mean air temperature and the mean temperature of evaporation at 3 a.m. are both 44°·6, but it is seen that the dry bulb is obtained from 25 days' observations, and the wet bulb from 20 days' only, so that practically no comparison is possible. In 1862 the July air temperature mean is obtained from 27 days, and the evaporation from 17 days. He regretted this want of judgment in the discussion, as he attached the very highest possible importance to the series of observations made at Greenwich, which in many ways stood unique in its position with regard to meteorology.

Mr. Rostron said that he agreed with Mr. Ellis that it was an utter fallacy to take averages of short series of years. Ten years was certainly much too short a period, and he did not consider 50 years was by any means too long. In fact, he was of opinion that for the purpose of meteorological averages the longer the series of years the better was the average obtained. He illustrated the truth of his remark concerning averages deduced from short series of years by instancing the air temperature at Greenwich in the month of October, which, during the 12

years 1855-1866 both inclusive, was continually in excess, but had now for several years past been in defect of the mean. The month of February, during the last 80 years, exhibits similar "eccentricities."

Mr. Tripp thought that if it were possible to discover cycles of years from such a series of observations as those placed before them by Mr. Ellis, the true mean should contain a due proportion of the high and low readings in each cycle.

Mr. Ellis said that in the table of mean temperature now presented the results depend on 24 hourly values on each day, adopting, as required, values from the eye observations for days on which the photographs were imperfect or wanting, so that the whole period is completely represented. Results depending in this way fundamentally on hourly temperatures necessarily supersede for the period in question all other values, and he hoped to see also published, in due course, the corresponding daily values from which the present monthly results are formed. For those who prefer the simple mean of the maximum and minimum temperatures, the Greenwich volumes have already continuously supplied the necessary information. He considered it to be quite possible that at different places the differences between the readings on an open stand and in a closed screen might not be similar, and yet be equally true for each particular case. It seemed to him that meteorologists too often expected an accuracy and an agreement of results not at present attainable. In regard to the 20 years' reductions, their value consists in the full and complete information afforded on the diurnal inequalities of meteorological elements in relation to which the omission of a few days in some months, owing to imperfect photographs, becomes of little practical importance. Photographic processes, a quarter of a century ago, had not the certainty of those of modern times. He did not understand the surprise expressed at the monthly means of air temperature therein contained varying from the means of the table now presented, since a little examination of the book would show that the monthly means collected in Table 52 are those appearing in Tables 38 to 49, against the columns containing which means is to be found another column giving the number of days in each month on which the several means depend. He thought that the collected monthly means of Table 52 should have been corrected for omitted days, but the work was not done under his direction, although he had to see it through the press. In two tables which, however, he was able to add to the 20 years' reductions, Tables 21 and 77, giving mean daily values of atmospheric pressure and of air temperature (a 20 years' average), he did take account of days on which photographs were wanting, as is noted in the introduction to the work. What has been said on the non-correspondence of days employed in the tables of air and evaporation temperatures, Tables 38 to 67, is likely to produce an erroneous impression as to the extent of such non-correspondence. In 20 years there are 240 months, and only in 8 months does non-correspondence exist, and in these the difference exceeds two days in a month on four occasions only, June 1858, May 1863, July 1861 and 1862. For the remaining 232 months the hourly values of the two elements are strictly comparative. All this is easily seen, as the tables themselves give complete information on these points. He did not say that it would not have been better to have avoided more completely such non-correspondence; he would have preferred to have done so; at the same time it should be understood that this affected the work only in a slight degree, and could not reasonably be said to detract from the real value of the results.

PHONOMETER.

By W. F. STANLEY, F.R.Met.Soc., F.G.S.

[Received May 22nd.—Read June 17th, 1891.]

This instrument, which is really a new form of chronograph, has been designed for the purpose of ascertaining the distance of a gun by observations of the flash and the report of its discharge, by noting the difference of time that light and sound take in reaching the observer. It is introduced to this Society for the object that it provides a means of measuring the distance of an electric discharge, by the difference of time between which lightning is observed in the flash and the following report of the thunder is heard, providing by this means an item of meteorological measurement not heretofore recorded.

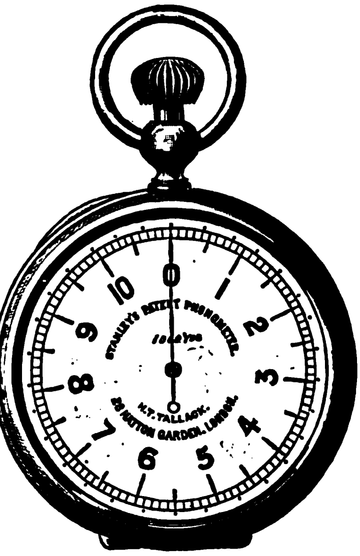
The manipulation of the phonometer is simpler than that of any form of chronograph, in that for complete indication of an observation, there is only one button to be pressed. This button acts by simple pressure in setting its time-going apparatus free, and stops instantly by the release of the pressure, leaving the indication, according to the divisions of the dial, either to the exact time between the pressure and the release, or the distance (calculated from the mean velocity of sound in air) in yards. This indication is without any calculation of difference of time as with the chronograph, as the time-going apparatus starts uniformly from zero at the instant of pressure, and entirely stops upon release of the pressure. The index-hand is afterwards returned to zero by a second pressure upon the same button employed in the observation, where it remains ready at any time for future use.

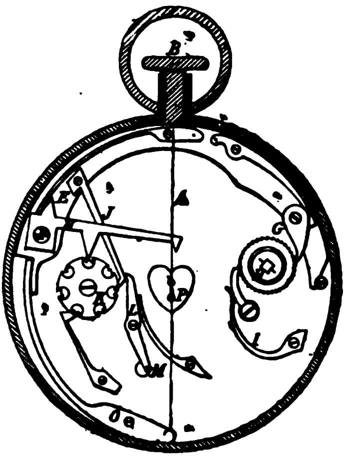
The construction of the Phonometer varies from a chronograph only in that it possesses additional parts. The chronograph, which is a constantly-going watch, requires most delicate manufacture to enable it to keep in order under constant wear. This instrument is going only at the time it is in use, by which there is no appreciable wear upon its most delicate parts, that may therefore be made to the highest degree of sensitiveness without danger of such parts becoming dull. This instrument is so constructed that the pressure given in returning the index-hand to zero shall also wind the spring more than sufficiently for another observation, means being at the same time provided that the spring cannot be overwound. There is, therefore, no key or winder required, and no risk that it shall not be ready at any moment for taking an observation. The index-hand makes the entire circuit of the dial in 30 seconds, but so long as the button is held down it goes on continuously, by which means as many half-minutes as desired may be taken. The half-minute revolution enables the dial to be made with very open space readings.

The details of the instrument, beyond the escape system of a perfectly sensitive chronograph for the going part, are shown in the diagram plan of the

instrument, which is represented with the outer case and dial removed, thereby showing the mechanism, which is worked by the pressure of the push *B*.

A is the index hand; *E* is a piece of steel, working on screw *F* when pushed down by the push *B*. *G* is a small pawl attached to steel piece *E*, which turns the ratchet wheel *H* connected to the mainspring arbor whenever *E* is pushed down by pushing *B*, the ratchet wheel *H* being held in position by pawl and spring *I*.





Connected also to the steel piece *E* is another pawl, *J*, which engages in lower part of the castle-wheel *K*, and partly revolves it when *E* is pressed down. This pawl *J* is extended to come in contact with the lever *L* when pressed down, and turns it slightly on its centre, which movement shifts the lower end carrying a pin *M* projecting inwards, and against the rim of the escapement wheel, away from the escapement wheel, thus setting the escapement free to work; at the same time the castle wheel *K* is partly revolved, which raises the lever *N* free from the heart-shaped frictional return piece for the index-hand. It will thus be seen that the act of pressing the push *B* partially winds the main spring, sets the escapement free, and raises the lever *N* from holding the index-hand at zero; and the act of releasing the pressure causes the steel piece *E* to return to its normal position by the spring *O*, thus removing the extension of pawl *J* from the lever *L*, which again stops the escapement wheel, leaving the index-hand at whatever distance it has travelled during the time the push was held down.

By pressing the push again the castle wheel *K* is arranged to drop the lever *N* upon the heart *P*, which returns the hand to zero, and the instrument is then ready to record again.

Beneath the plate carrying the above described mechanism the ordinary train of wheels of a chronograph are arranged.

DISCUSSION.

Mr. [illegible] said that the instrument was extremely ingenious, but he should like to know how the arrangement was actuated and released so quickly.

Mr. [illegible], in reply, said that in this instrument, as in all chronographs, the arrangement was constructed on what was known as the cylinder principle. When the button at the top was pressed, a slightly-inclined cam started the arrangement, and so set the instrument in motion. Its action being almost instantaneous, the impact probably did not occupy the [illegible] part of a second.

SOME SUGGESTIONS BEARING ON WEATHER PREDICTION.

By ALEX. B. MACDOWALL, M.A.

[Received April [illegible].—Read June [illegible], 18[illegible].]

The following suggestions, arising out of a recent study of certain records, may perhaps be not unworthy of the Society's consideration. They relate to three things: I. The distribution of rainfall in the year; II. Days of rain in June to September; III. What may be called "Waves of Sunshine."

I. *The distribution of rainfall in the year.*—If we take the monthly amounts of our rainfall in a series of years, and make a smoothed continuous curve of them, smoothed by means of three month averages, we find in most years a pretty obvious maximum for the year; usually the crest of a wave, which slopes more or less regularly for several months on either side.

Consider these maxima in the yearly curves, and the intervals between them. Taking the Chiswick record from [illegible] to 1869, and the Greenwich record from 18[illegible] to 18[illegible], it appears that while the maxima occur most often, as might be expected, in the autumn months (October having most), they may be found, apparently, in any month of the year (unless March be excepted, which, in this series of 5[illegible] years, never shows a maximum).

The three months represented in each of these highest points have (in general) the highest three consecutive months' rainfall of the year. (Where the highest point occurs in January or December, a month of the adjoining year, before or after, is included in the consideration.) What proportion (it may be asked) have these three months of the total rainfall of the year? From an examination of the latter half of the period, they seem to have, on an average, about [illegible]ths of the total; that is, nearly one-half. But in some cases the amount is over one-half, and in others it goes down under one-third.

The interval from one yearly maximum to the maximum of the next year is seldom exactly a year; and seldom the same length in one case as it was in the case just before. As a rule, it alternately lengthens and shortens; if in

one year longer *e.g.* than in the year before, next year it is shorter than this longer one, and so on. This will appear from the following table, which gives for each year the number of the maximum month, and the length of the interval it terminates :—

Year.	No. of max. months.	Interval in months.	Year.	No. of max. months.	Interval in months.
1840	10	...	1866	2	5 *e*
1841	10	12	1867	8	18
1842	10	12	1868	12	16
1843	6	8	1869	1	1 *e*
1844	10	16	1870	11	22
1845	12	14	1871	8	9
1846	9	9 *e*	1872	11	15
1847	11	14	1873	1	2
1848	7	8	1874	10	21
1849	8	13	1875	8	10
1850	12	16 *e*	1876	12	16
1851	2	2	1877	1	1
1852	10	20	1878	5	16
1853	7	9	1879	7	14
1854	6	11	1880	10	15
1855	6	12 *e*	1881	9	11
1856	9	15 *e*	1882	10	13
1857	9	12	1883	10	12
1858	6	9 *e*	1884	12	14
1859	9	15	1885	10	10
1860	6	9	1886	11	13
1861	12	18	1887	10	11
1862	4	4	1888	7	9 *e*
1863	9	17	1889	6	11
1864	10	13	1890	7	13 *e*
1865	9	11 *e*			

This table further shows that the rule, as just indicated, is not universal. Excluding two cases at the outset, where the interval is exactly a year, we find ten exceptions (or exceptional years, marked *e* in table). These anomalies are of the following nature: (1) Lengthening of the interval twice in succession after a normal lengthening (2 years); (2) Shortening twice in succession after a normal shortening (2 years); (3) Lengthening once after a normal lengthening (2 years); (4) Shortening once after a normal shortening (4 years). The curve of those variations is normally, then, a zig-zag one, with a relative maximum every second year; and likewise a relative minimum.

The intervals between the maxima in our principal curve vary in length from one to 22 months. The exceptions seem to have occurred chiefly in periods of rainfall that were generally under average; and in some of the exceptional years the maximum is not very pronounced.

We have here, then, it is suggested, a means of estimating beforehand, with considerable reason, whereabouts in a commencing year (*i.e.* before or after such and such a month) the maximum (as above explained) will probably fall; that is, we have indications where we should look for the three consecutive months giving the greatest (three consecutive months) rainfall. If the maximum of last year was further apart from the one just before, than that from the one before it, we should expect the current interval to be shorter than the last; in the opposite case, longer.

It may be mentioned that the rainfall data for Paris give very similar results.

II. *Days of rain in June to September.*—The well-known saying about St. Swithin's Day is of course often falsified by observed facts. But the widespread idea, evidently related to it, that wet or dry weather, coming about the time of the summer solstice, has a tendency to persist, appears to find some vindication in experience.

I propose to offer here some evidence for the proposition that "the total number of days of rain (·01 in. and over) in July to September varies, on the whole, with the number of days of rain in June."

The data are presented in the following table; the stations selected being Barnstaple, Borrowdale (Seathwaite), Aberdeen, Chiswick, and London. The figures for the first three are obtained from Mr. Symons's *Meteorological Magazine*.

Days rain June.	No. of cases.	Average Days rain July-Sept.	Extremes July-Sept.
Barnstaple (1866-88).			
0 to 8	7	39·7	29—55
Over 8 to 12	6	46·2	36—59
Over 12 to 16	5	49·6	42—61
Over 16	4	55·0	53—63
Borrowdale (Seathwaite) (1866-88).			
0 to 11	8	52·2	39—61
Over 11 to 15	5	59·6	48—67
Over 15	8	61·8	46—75
Aberdeen (1866-88).			
0 to 11	7	48·7	35—59
Over 11 to 16	8	50·7	34—64
Over 16	7	57·4	44—70
Chiswick (1826-69).			
0 to 8	11	34·1	22—44
Over 8 to 12	11	39·2	32—52
Over 12 to 16	12	40·8	28—60
Over 16	10	44·6	36—58
Greenwich (1870-89).			
0 to 7	6	35·6	28—41
Over 7 to 12	6	37·6	33—43
Over 12	8	43·4	37—53

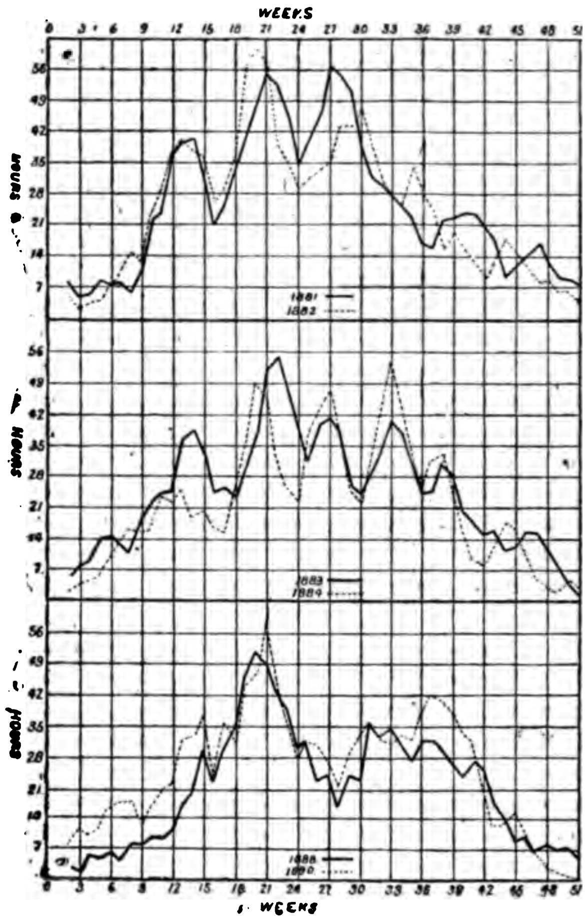
The plan adopted is first to classify the years (in the periods indicated for each station) according to the number of days of rain in June (0 to 8, over 8 to 12, and so on); then, putting down for each year in a given group the total number of days of rain in July to September, to take the average of those totals for the group. We thus get an ascending series of averages for each station, with an ascending series of days of rain in June. Thus, in the case of Barnstaple (perhaps the best example), we have, with 0 to 8 days' rain in June, 39·7 days' rain in July to September, on an average of seven years; and the average rises in the next two groups, till, with over 16 days' rain in June, we have 55 days' rain, on an average, in July to September; showing an extreme difference of 15·3 days. The extremes of variation of the number of days of rain in July to September are also indicated for each group; and it will be seen that while the maxima and minima both form in general ascending series, this rule is occasionally broken, and the range is in any case wide; which, no doubt, detracts from the practical value of the facts. Yet some useful indications, it seems to me, might be derived from this view of the case, especially where June is found to be considerably above or below its average of days of rain. Thus, recurring to Barnstaple, consider what we have to guide us in forecasting the number of wet days from July to September. Apart from a consideration of June, we have the general average number of days' rain in those three months (say 46), representing, let us suppose, the maximum of probability; with a possible range (according to those 22 years) from 29 to 63 (or 34). Considering June, on the other hand, we have, with a dry June, an average of about 40 days' rain in the next three months, with a wet June, an average of 55. And the probability may be supposed to diminish from those averages to the extremes of 29 and 55 in the one case, and 53 and 63 in the other. The series of years is here too short; and I make use of it merely to show how the principle may be applied, and how some little advantage, in greater definiteness of forecast, may possibly attach to its application.

III. *Waves of Sunshine.*—I would invite attention to the smoothed curves of bright sunshine obtained from the weekly Greenwich values (smoothed by means of three weeks averages). The accompanying diagram contains six of these as specimens (viz. for the years 1881, 1882, 1883, 1884, 1888, and 1890).

One feature apparent in many of these curves is the succession of distinct, more or less regular waves, varing in number up to six or seven at most in the year. Then the same type of curve tends to recur, apparently, the maxima of both, perhaps, even falling about the same time; and likewise the minima. Thus one sees at once the general correspondence of 1884 with 1883, and of 1890 with 1888. In the latter pair we have two maxima coincident in time at the 15th week; then a more pronounced maximum in the 20th week of one year and the 21st of the other; then a deep cleft in both curves at the 28th week, while the remainders are generally alike.

Again, considering the intervals between pronounced maxima (40 cases), the most common length seems to be about six weeks; and about three-fourths of the whole are between five and nine weeks.

Another line of inquiry is as to what particular fixed times in the year such relative maxima and minima of sunshine tend to be incident. For apparently there is such a tendency. Perhaps a longer series than this of Greenwich is required to determine the matter satisfactorily, and I cannot profess to have worked it out on the present data; but attention may be called to the 21st week (about the end of May), which appears generally to be a sunny centre; while the 16th and 24th weeks have rather an opposite character.



Weekly Sunshine at Greenwich.

Once more, the general character of the curves seems to vary from time to time between complexity and simplicity. Thus the last pair may be described as simpler than those above; they have fewer distinct waves. (1889 is somewhat similar to its two neighbours here given). It is known that 1883 was a time of maximum sunspots, and 1889 one of minimum; and one

is disposed to ask, Might this have anything to do with the curious difference of type of the curves about those two years? The series is too short to warrant an opinion on the point; but perhaps the matter is worth looking into when more observations are available.

The general line of investigation suggested, then, is by a careful study of the entire series of such curves (since 1877) to form some idea (which appears to be possible) as to where those three weeks' relative maxima and minima of sunshine in a commencing or current year are likely to recur.[1]

PROCEEDINGS AT THE MEETINGS OF THE SOCIETY.

MAY 20th, 1891.

Ordinary Meeting.

BALDWIN LATHAM, M.Inst.C.E., President, in the Chair.

MICHAEL GEORGE FOSTER, M.A., M.B., Alassio, Riviera di Pomente, Italy; and
JOHN ROBINSON, J.P., Westwood Hall, Leek,
were balloted for and duly elected Fellows of the Society.

Mr. SYMONS stated that the subscriptions promised to the New Premises Fund amounted to £1,157 2s.

The following Papers were read:—

"ON THE VERTICAL CIRCULATION OF THE ATMOSPHERE IN RELATION TO THE FORMATION OF STORMS." By W. H. DINES, B.A., F.R.Met.Soc. (p. 208.)

"ON BROCKEN SPECTRES IN A LONDON FOG." By A. W. CLAYDEN, M.A., F.R.Met.Soc. (p. 209.)

"AN ACCOUNT OF THE 'LESTE,' OR HOT WIND OF MADEIRA." By H. COUPLAND TAYLOR, M.D., F.R.Met.Soc. (p. 217.)

Mr. SHELFORD BIDWELL, M.A., F.R.S., also exhibited an Experiment showing the effect of Electrification upon the condensation of Steam. (p. 258.)

JUNE 17th, 1891.

Ordinary Meeting.

BALDWIN LATHAM, M.Inst.C.E., President, in the Chair.

JEREMIAH JAMES COLMAN, M.P., Carrow House, Norwich;
ERNEST B. DUKOFF-GORDON, B.A., Allahabad, N.W. Provinces, India;
GEORGE EDWARD LEON, Bletchley Park, Bletchley;
THOMAS DE COURCY MEADE, M.Inst.C.E., The Park, Highgate, N.; and
FRANK RUSSELL, F.R.G.S., 16 Montrell Road, Streatham Hill, S.W.,
were balloted for and duly elected Fellows of the Society.

[1] I may state that I have made out curves for all those years, and they are to open inspection by any one who may wish to see them.

The following Papers were read:—

"A CURIOUS CASE OF DAMAGE BY LIGHTNING." By ALFRED HANDS, F.R.Met.Soc. (p. 226.)

"ON THE MEAN TEMPERATURE OF THE AIR AT THE ROYAL OBSERVATORY, GREENWICH, AS DEDUCED FROM THE PHOTOGRAPHIC RECORDS FOR THE FORTY YEARS FROM 1849 TO 1888." By WILLIAM ELLIS, F.R.A.S., F.R.Met.Soc. (p. 233.)

"ON THE COMPARISON OF THERMOMETRICAL OBSERVATIONS MADE IN A STEVENSON SCREEN WITH CORRESPONDING OBSERVATIONS MADE ON THE REVOLVING STAND AT THE ROYAL OBSERVATORY, GREENWICH." By WILLIAM ELLIS, F.R.A.S., F.R.Met.Soc. (p. 240.)

"PHONOMETER." By W. F. STANLEY, F.G.S., F.R.Met.Soc. (p. 250.)

"SOME SUGGESTIONS BEARING ON WEATHER PREDICTIONS." By ALEX. B. MACDOWALL, M.A. (p. 252.)

CORRESPONDENCE AND NOTES.

AN EXPERIMENT SHOWING THE EFFECT OF ELECTRIFICATION UPON THE CONDENSATION OF STEAM. By SHELFORD BIDWELL, M.A., F.R.S.

WATER is boiled in a small tin bottle, furnished with a cork through which passes a glass tube terminating in a nozzle of about 1-16th inch aperture. The shadow of the steam as it issues from the nozzle, when cast upon a white screen by a powerful light, appears under ordinary conditions to be of feeble intensity and of a neutral grey tint, showing that the steam is nearly transparent. But if a discharge of electricity is directed upon the base of the jet of steam by means of a bundle of needle points in connection with an influence machine, the shadow at once becomes dark and dense, at the same time assuming, especially near its edges, a peculiar orange-brown hue. The electrical discharge appears to act by promoting coalescence of the exceedingly minute particles of water contained in the jet, thus forming drops large enough to obstruct the more refrangible rays of light.

The experiment suggests a possible explanation of the intense darkness of thunder clouds, as well as of the lurid yellow glow by which such clouds are often distinguished.

FURTHER NOTE ON THE RELATIVE PREVALENCE OF DIFFERENT WINDS AT THE ROYAL OBSERVATORY, GREENWICH. By WILLIAM ELLIS, F.R.A.S., of the Royal Observatory.

THE paper which I communicated last year to the Royal Meteorological Society on the above question[1] was prepared with the object of showing whether the increased prevalence of North-east winds which Mr. Prince had found in recent years to exist at Crowborough was indicated also by the Greenwich records. In that paper I compared together the results obtained by Mr. Prince from one observation daily at 9 a.m., with results for Greenwich taking into account the whole twenty-four hours. This was done simply because the Greenwich results existed in such shape available for immediate use. Mr. Prince took exception at the time to the comparison made in this way, and indicated his belief, as I understood, that if the comparison of his results had been made with corresponding Greenwich results, that is with such as would have been obtained by discussion of the observed indication of the wind at 9 a.m. only, much of the discordance would

[1] *Quarterly Jour*, Vol. XVI, page 221.

have disappeared. I am afraid that I may not have appeared to give due attention to his remarks on this point, one reason that weighed with me perhaps being that my examination of the Osler anemometer record, day by day, through a long series of years, had certainly not impressed me with any idea that the difference in the results found for the two places could be due to the circumstance that, in the discussion of the Greenwich winds, the whole day was considered, instead of 9 a.m. only.

In Mr. Prince's Report for the year 1890, of which he has kindly favoured me with a copy, I observe that he reiterates his objection to the method of comparison adopted. It seems, therefore, desirable to make the comparison in the way suggested by him. It happens that the Meteorological Report that we send daily to the Meteorological Office, and in other directions, includes the direction of the wind at 9 a.m. as taken from the anemometer record. These directions I have now discussed for the years 1885 to 1889 to which Mr. Prince again refers. Unlike the results before given, these have been tabulated as referred to sixteen points of the compass, instead of eight. And since it is not a new extraction from the Osler record that is now made, but simply the employment of the daily directions of wind as given in reports all prepared before the discordance mentioned by Mr. Prince was (in the year 1890) pointed out, any possibility of individual bias in the preparation of the results becomes removed. In saying this I cast no reflection, wishing simply to make clear the thorough independence of the Greenwich result.

TABLE I.—Number of Days of Prevalence of Different Winds in each Year, 1885 to 1889, as derived, at 9 a.m. on each day, from the records of the self-registering Osler Anemometer of the Royal Observatory, Greenwich.

Year.	N.	NNE	NE.	ENE.	E.	ESE.	SE.	SSE.	S.	SSW.	SW.	WSW.	W.	WNW.	NW.	NNW.	Calm.
1885	24	28	30	23	12	20	7	6	17	44	46	46	12	11	5	19	15
1886	20	20	31	25	12	16	7	6	20	37	45	59	18	11	2	17	19
1887	32	42	30	19	10	5	3	6	14	23	46	59	14	6	3	15	38
1888	27	32	31	12	13	12	6	12	18	41	46	53	14	12	10	7	20
1889	30	27	29	10	12	11	8	9	12	40	56	47	23	5	6	13	27
Mean	26	30	30	18	12	13	6	8	16	37	48	53	16	9	5	14	24

To reduce the numbers of Table I. to eight points of the compass, half the number of days of North-north-west wind, and half the number of days of North-north-east wind were in each year added to the number for the North wind, and so on. The results as referred to eight points are contained in Table II., adding thereto the previous Greenwich means, and also the Crowborough means.

TABLE II.—Number of Days of Prevalence of Different Winds as given in Table I. referred to Eight Points of the Compass.

Year.	N.	NE.	E.	SE.	S.	SW.	W.	NW.	Calm.
1885	48	55	34	20	42	91	40	20	15
1886	38	54	32	18	42	93	53	16	19
1887	61	60	22	9	28	87	47	13	38
1888	46	53	25	18	45	93	46	20	20
1889	50	48	22	18	37	99	49	15	27
Mean, Greenwich 9 a.m. direction	48	54	27	17	39	92	47	17	24
Mean from previous paper, Greenwich whole day direction	49	52	35	23	37	100	40	19	10
Mean, Crowborough 9 a.m. direction ..	41	102	21	22	38	72	50	17	..

By the substitution of the 9 a.m. direction for that for the whole day at Greenwich, the mean number of days of North-east wind becomes increased from 52 to 54, and the number of days of South-west wind decreased from 100 to 92, both changes, though small, being in the direction of bringing the numbers more into harmony with those of Mr. Prince. But the new Greenwich numbers for North-east and South-west winds are still widely different from those of Mr. Prince. The difference is, therefore, not to be explained in the way supposed. One curious point is that the numbers for other winds are in general in good agreement.

THE "IGNIS FATUUS," OR, WILL O' THE WISP. By F. RAMSBOTHAM, F.R.Met.Soc.

FOR some years now, since I have been living at the Warren, Crowborough, in Sussex, I have, in common with many others, been struck by seeing Will o' the Wisp, or *Ignis Fatuus*, playing about in the evening at various times, sometimes in one place, sometimes in another, and sometimes two at once, but not in the same place. Now I have observed that these appearances always coincide with unsettled weather, that is, that bad weather has invariably followed their appearance—in fact, it is quite a storm warning to us, as bad weather is sure to follow sooner or later, generally sooner.

On Saturday, September 26th, 1891, one of my brothers and myself watched one for some time, and last night (October 1st) it appeared in the same place and was visible quite half-an-hour. It does not dance about, but now and then takes a graceful sweep, now to quite a height, and then makes a gentle curve downwards, after sparkling and scintillating away for ten minutes or more.

In the winter there is generally a very remarkable one which appears to rise in Ashdown Forest beyond this estate, which I have known to keep steadily in the air for half-an-hour, and then sail away a long space and stop again. Our keeper has seen it dozens of times, and in every case bad weather followed.

SOUTH AFRICAN WEATHER 1890-91. By CHARLES COWEN.

MR. COWEN, in a letter from Johannesburg, dated April 1891, says:—"Nearly every mail from beyond the Equator to South African ports, for months past, has brought news of the phenomenal winter which has covered the European belt of the northern hemisphere, increased mortality to an unusual degree, and done vast damage to property.

"To readers on the northern side of the globe, it may be of interest to have attention drawn to what has been transpiring meteorologically on this side; and for some to consider whether beneficial results of any kind may be obtained by extending systematic observations to at least the principal parts of this Continent, now being widely embraced by the white race, in addition to what is done by the Meteorological Commission of the Cape of Good Hope, whose observers touch Bloemfontein in the Orange Free State, and Johannesburg and Rushenburg in the Transvaal.

"While the winter in Europe and North America has been one of greater hardness, and its range wider than has been known for many years, the corresponding period (our summer), in portions extending from Zambezia towards the Cape, has been remarkable for the rains and storms that have prevailed. They began in the Transvaal at an unusually early date; and I find that the Free State, Natal, the Transkeian Territory, and sections of the Colony had these early downpours as we have had them—often accompanied by high winds and heavy electric storms, with brief intervals to the present time. Many of these fierce storms synchronised with distressing snowfalls and extreme frost on the northern half of the globe (reported to us by cablegram).

"I do not give details here, because too many of them would be required to be of practical use to the readers of so brief a paper as this must be. Those who care to follow up the subject will find all the information at present recorded in the files of South African newspapers at the Royal Colonial Institute, the offices of the Agent-General for the Cape of Good Hope, Sir Charles Mills, K.C.M.G., the Crown Agents for Natal, and the Consuls-General in London for the South

African Republic and the Orange Free State. There too, they will find, at least with Sir Charles Mills—I do not know what the others may have—the Annual Reports of the Cape Meteorological Commission, and maps of rainfall for years past, with which they can compare as much information as a newspaper will give them of our latest seasons' rains. But the following may be mentioned here:—

"The rains on the East Coast and the high inland plateaux have been less steadily from the South-east than they usually were. The downpour has come from several quarters in succession, and everywhere more prolonged in duration and far greater in quantity than ordinarily.

"In Basutoland the rains were later than they should have been, but they have made up in quantity and persistence what they wanted in punctuality of recurrence.

"The wet season varies, of course, in South Africa, not only according to the latitude of the several countries, but to the usual physical conditions which affect the copiousness and the reverse of rains. But throughout the Continent the rains of 1890-91 have been excessive. What the averages will be, it is not possible to state at present. On the West Coast of the Cape Colony, a cold South Atlantic current sweeps; and on the East Coast, one so much warmer that at False Bay it is 15° higher in temperature than at Table Bay—a sandy, low level strip of land, 20 miles broad, separating the two Bays from one another."

Mr. Cowen then refers to the excellent work accomplished by the Cape Meteorological Commission, and suggests that much more information on the meteorological condition of the various countries of South Africa might be obtained if the interest and cooperation of several companies and gentlemen were secured in the matter.

He then goes on to say:—"Climatic conditions of new countries must influence emigration, and emigration trade. There are parts of the Transvaal equal to the most balmy lovely spots upon the globe, and some like Scotland, none like Manitoba or Labrador, but some valleys where fever reigns and people die, and some parts where longevity is common. There are portions of Bechuanaland where no white man should settle, and others again within its limits which would give new life to thousands of the over-crowded people of the United Kingdom; while parts of Mashonaland are described as a very land of Beulah, and certain river and coast stations as the grave of the white man.

"Under the existing seething condition of life in the mother country, when public thought is strained to know what best to do with the surplus population, it must surely be of some consequence to know also reliably the climatic character of the countries to which some of that surplus may be sent, and to devise machinery for regularly obtaining that information. Thus, for climatic reasons all whites have to clear out of part of the country towards portions of the Zambezia in November, if they will not leave their bones there. There is a time of the year when travelling by the Delagoa Bay route to and from the Transvaal is dangerous, and another when it may be done with impunity. So, too, with portions of this last-named grand country in which Britons have acquired millions of acres—some areas are notably healthy all the year round, others northward and eastward are to be avoided as one would avoid the Upas Valley of Java; and some of these Valleys of the Shadow of Death change their characters as fire and civilisation systematically approach them, just as the tsetse fly has disappeared with the extinction of large game."

The Meteorology of South West Africa.

Dr. H. Schlichter, in a paper[1] on "The Geography of South West Africa," which was read at the recent Meeting of the British Association at Cardiff, gives the following account of the meteorology of that district, which is, however, only imperfectly known, as only quite recently meteorological observations have been commenced at some of the missionary stations.

There are two distinct seasons, viz. the hot or rainy and the dry. The former, in which most of the rain falls, lasts from November to May, and the latter

[1] *The Scottish Geographical Magazine.* Vol. VII. p. 484.

during the rest of the year. The rains seldom last long, but fall very heavily, and with the thunder which accompanies them, proceed regularly from east to west towards the Atlantic. In the dry season the sky is often cloudless for months together; but as a rare occurrence it has happened that, even in this part of the year, rain has fallen not only in Herero-land but also in the interior, on the highlands of the North-western Kalahari and the Omaheke. The meteorological phenomena near the Atlantic coast are in many respects analogous to those on the west coast of South America. The cold Benguela current coming from the south is the cause of the very low temperatures observed there; Walvisch Bay, for example, having an average annual temperature of 63° Fahr., and often bitterly cold nights. Cold mists rising from the sea at night time, and saturating everything with moisture, are of regular occurrence along the coast, to which, however, they are limited, very seldom being met with at Otjimbingue and other places more in the interior. To a certain degree these mists are the only substitute for the rain, which is almost entirely absent in the desert coast region. This absence is due chiefly to the West and South-west winds, which blow regularly for a longer or shorter period every day, and carry inland the little moisture which rises from the cold Benguela current, so that no rainfall near the coast is possible. But also the more eastern districts receive only irregular supplies of rain from this moisture, as the winds blow during the day, when the heat of the ground is usually very great, and, therefore, produces an upward current of air, so that thunderstorms and heavy rains are the chief characteristics of the wet season. It appears from this, that no definite distinction should be made between the meteorology of the central parts of Herero- and Nama-lands and that of the Kalahari Desert, as the winds are not dessicated by passing over high mountain ranges, but are without sufficient moisture from the above-mentioned circumstances. The scarcity of rains in the Kalahari is owing chiefly to its greater distance from the Atlantic: but that thunderstorms and heavy rainfall do occasionally occur in the eastern parts of the country, even in the neighbourhood of Lake Ngami, is recorded by various travellers. With regard to the distribution of the rainfall, it may be remarked that more falls in the northern than in the southern parts of South West Africa; and near the Orange River there are certain districts which are said to be entirely rainless.

RECENT PUBLICATIONS.

American Meteorological Journal. A Monthly Review of Meteorology and Medical Climatology. July-September 1891. 8vo.

The principal contents are:—Franklin's Kite Experiment: by A. McAdie (11 pp.).—Cloud Heights and Velocities at Blue Hill Observatory: by H. H. Clayton (15 pp.).—Meteorological Kite-Flying: by W. A. Eddy (3 pp.).—The Samoan Hurricane of March 1889: by E. Hayden (15 pp. and 2 plates).—Mountain Meteorology: by A. L. Rotch (3 pp.). This contains extracts from a series of three lectures delivered before the Lowell Institute of Boston.—On the various kinds of Gradients: by L. Teisserenc de Bort (5 pp.).—The Climatic History of Lake Bonneville: by R. De C. Ward (7 pp.).—Water-Spouts: by Prof. Cleveland Abbe (4 pp.).—The Aspiration Psychrometer and its use in Balloons: by Dr. R. Assmann (6 pp.).—The Bergen Point Tornado: by W. A. Eddy (5 pp.).—The Hot Winds of California: by Lieut. J. P. Finley (6 pp.).—Altitude and Hay-fever: by Dr. W. J. Herdman (3 pp.).

Cyclone Tracks in the South Indian Ocean, from information compiled by Dr. Meldrum, C.M.G., F.R.S. Published under the Authority of the Meteorological Council. 1891.

This comprises a series of yearly charts showing the tracks which Dr. Meldrum has been able to lay down of all the cyclones in the South Indian Ocean for which he had received information as having occurred between the years 1848 to 1885. No reports of cyclones were received from Dr. Meldrum for the years 1849, 1850, and

1853. From the yearly series of charts has been prepared a monthly series, with a view of grouping together the storms occurring in the successive months of the year. The monthly charts are only nine in number, no cyclones having been recorded in either August or September, and the number in June and July being so limited that the information for these two months is shown on one sheet. In dealing with these cyclones Dr. Meldrum has divided them into "Progressive" and "Stationary." The very marked difference in the proportion of Progressive storms to those classed as Stationary in the different months of the cyclone season is a valuable fact for the seaman, if it can be considered established. The knowledge that in the early and late months of this season the chances are about even that a cyclone is stationary, and that in the height of the season the chances are very great that a cyclone is in rapid progression would greatly influence the action of a vessel that finds herself in the neighbourhood of a storm, but, though these proportions are too strongly marked throughout this long series of years to admit of much doubt that the ratio between the Progressive and Stationary Cyclones is different in the different parts of the season, the doubt whether full information of every storm has been obtained must prevent the proportions as herein given being accepted as absolutely correct.

The distribution of the available material, and the relative frequency, for the whole series of 33 years, for the several months are as follows:—

Month.	Progressive Storms.		Stationary Storms.		Totals.	
	Total.	Frequency.	Total.	Frequency.	Stationary and Progressive.	Frequency.
October	2	1 in 18 years	3	1 in 12 years	5	1 in 7 years
November	12	1 " 3 "	13	1 " 3 "	25	5 " 7 "
December	23	2 " 3 "	10	2 " 7 "	33	1 " 1 "
January	52	3 " 2 "	19	1 " 2 "	71	2 " 1 "
February	55	5 " 3 "	6	1 " 6 "	61	5 " 3 "
March	40	4 " 3 "	19	1 " 2 "	59	5 " 3 "
April	26	3 " 4 "	24	2 " 3 "	50	3 " 2 "
May	8	2 " 9 "	11	1 " 3 "	19	1 " 2 "
June	1	1 " 35 "	2	1 " 18 "	3	1 " 12 "
July	1	1 " 35 "	1	1 " 35 "	2	1 " 18 "
Yearly	220	..	108	..	328	..

Denkschrifte der Mathematisch-Naturwissenschaftlichen Classe der Kaiserlichen-Akademie in Wien. Band LVIII. 1891. 4to.

Contains: Die Veränderlichkeit der Temperatur in Oesterreich: by Dr. J. Hann (80 pp.). This is a most elaborate discussion of the variability of temperature at the Austrian stations. It chiefly refers to the decade 1871-90, but in it we find the variability for Vienna for the 91 year period 1800-90. The most interesting portion of the paper is that dealing with the change of variability with height above sea-level, as naturally in Austria the stations at high levels are comparatively abundant, and Dr. Hann is admittedly the highest authority on mountain climate. In contrast to our own islands we may say that he finds that sudden serious falls of temperature are more frequent than sudden rises of equal amount.

Health: The Voyage to South Africa, and Sojourn there. 1891. 8vo. 78 pp. Maps and Illustrations.

The information in this book was collected and republished in a convenient form on the occasion of the assemblage in London in August 1891 of the International Congress of Hygiene and Demography, whom the manager of the Castle Mail Packets Company entertained at luncheon on board the South African Royal Mail Steamer *Drummond Castle*. The first part of the work deals with "The

Cape as a Health Resort," and contains papers on (1) The Cape Peninsula, by C. L. Herman, M.B.; (2) Graham's Town and the Eastern Districts, by the Hon. W. G. Atherstone, M.D.; (3) The Central Karroo Districts, by H. W. Saunders, M.B.; and (4) The Upper Karroo Plateau, by J. Baird, M.D. The second part contains a paper on "South Africa as a Health Resort," by E. S. Thompson, M.D., which has been reprinted from the Proceedings of the Royal Colonial Institute. Then follows an account of voyage out to South Africa, and other useful information.

Meteorologische Zeitschrift. Redigirt von Dr. J. Hann und Dr. W. Köppen. July to September 1891. 4to.

The principal contents are:—Zur Theorie der Cyklonen: von W. von Bezold (7 pp.). This is a summary of a Paper by the author in the *Sitzungsberichte* of the Berlin Academy for December 1890, in which he endeavours to explain cyclonic phenomena on the principles established by Hann and others, and attempts to reconcile the views as to descending whirlwinds held by M. Faye with the generally accepted ideas of modern meteorologists.—Mittheilungen aus dem Norwegischen Meteorologischen Institute: von H. Mohn (13 pp.). This is an account of the mode of discussion of meteorological results at present in practice in the Norwegian Institute.—A. Buchan über den täglichen Gang der meteorologischen Elemente auf dem Ocean und über die Vertheilung der Temperatur, des Luftdruckes und der Winde auf der Erdoberfläche: von Dr. J. Hann (12 pp.). This is a careful résumé of Mr. Buchan's report on Atmospheric Circulation.—Die Stürme der Adria: von R. R. von Jedina (12 pp.). This is an endeavour to explain the frequent storms of the Adriatic, and to show how to employ weather charts for their prediction.—Elecktrische Beobachtungen auf dem Hohen Sonnblick: von J. Elster und H. Geitel (14 pp.). This is an account of a fortnight's experiments on Atmospheric Electricity, carried ont by the authors on the Sonnblick and at Kulm-Saigurn, the station at the foot of that mountain. The results are of great interest to anyone investigating the subject, but we shall only extract what is said about St. Elmo's Fire. This appears with every thunderstorm, and is as often negative as positive. Whenever a flash is blue it is followed by negative, and when red by positive, St. Elmo's Fire.

Report on the Meteorology of India in 1889. By John Eliot, M.A., Meteorological Reporter to the Government of India. 4to. 640 pp. and 10 plates. 1891.

This is the fifteenth Report and the fifth of the second decade, and gives the results in the same form as in previous years of the observations recorded at 90 stations. The rainfall stations number 506. Mr. Eliot finds that "the meteorology of the three years—1887,1888, and 1889—present many points of resemblance in their larger abnormal features, more especially in the following:—1. In each year the cold weather rains in the plains of Northern and Central India were favourable, and either normal or in moderate excess. They were most abundant in 1889. On the other hand, the snowfall over the Himalayan area was less than usual, and the snow accumulation undoubtedly below the normal. 2. Hot weather conditions in March, April, and May were more pronounced than usual, and produced the same large effects on the pressure distribution, the most important being increased pressure or positive pressure anomalies in Southern India, and deficient pressure or negative pressure anomalies in Northern India. 3. The conditions and distributions of pressure in May were in each year favourable to the early establishment of a strong and steady South-west Monsoon. 4. The rains were unusually steady from June to August, but withdrew suddenly from North-Western India (*i.e.* Punjab, Rajputana, Central India, and the western districts of the North-Western Provinces) very early in September. 5. The rainfall in Madras and Southern India, generally due to the retreating South-west Monsoon, was favourable in the years 1887 and 1888, and on the whole sufficient in 1889, except in the southern districts of Madras. 6. The rainfall distribution of the three years was, on the whole, favourable, and was sufficient for agricultural operations, except in the following areas, where droughts caussd a partial or almost entire loss of the crops, viz. 1887, Partial drought in Guzerat and Kathiawar; 1888, Severe and prolonged drought in

Ganjam and South Orissa and the adjacent hill districts, which resulted in famine, and partial drought and failure of the crops in a small narrow area in North Behar; 1889, Partial drought and failure of the crops in the southern districts of Madras, more especially Tinnevelly, Madura, Trichinopoly, and Coimbatore."

Sitzungsberichte der Kaiserlichen Akademie der Wissenschaften in Wien. Bd. C. Abth. II. April 1891. 8vo.

Contains: Studien über die Luftdruck- und Temperaturverhältnisse auf dem Sonnblickgipfel, nebst Bemerkungen über deren Bedeutung für die Theorie der Cyclonen und Anticyclonen: von Dr. J. Hann (86 pp.). This a discussion of the barometrical and thermometrical extremes registered at the top of the Sonnblick (10,200 ft.) as compared with the simultaneous readings at Ischl during the past four years. Dr. Hann finds that in winter barometrical maxima above are always associated with maxima at the lower level. In winter also the changes of temperature on the summit, which accompany the passages of anticyclones and cyclones respectively, are exactly opposite to those observed at lower levels. The greater part of the communication is taken up with a reply to some criticisms of the author's views on the origin of cyclones, &c., which have appeared in *Science* during last winter.

Symons's Monthly Meteorological Magazine. July to September 1891. Nos. 306-308. 8vo.

The principal Articles are: Producing Rain artificially (2 pp.).—The United States Weather Bureau (2 pp.).—The Theory of Halos and Parhelia: by T. W. Backhouse and Rev. A. K. Cherrill (3 pp.).—Sunshine Recorders: by J. Baxendell (1 pp.).—On Cloud at Greenwich (2 pp.).—Indian Monsoon Forecasts (4 pp.).—Sunshine and Sunlight: by F. C. Bayard (1 p.).—Something like a Shower: by G. J. Symons (1 p.).—Meteorological Bibliography: by G. J. Symons (4 pp.).—A Rainy August (7 pp.).

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THE END.

DAMAGE BY LIGHTNING TO CHRISTCHURCH, NEEDWOOD, APRIL 5TH 1891.